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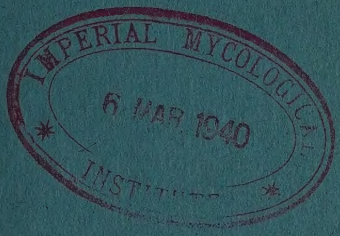

VOLUME XXV

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MATHÉMATIQUES

SUR LA NON-FLEXIBILITÉ DES OVALOÏDES

Par O. K. ZHITOMIRSKY

(Présenté par I. M. Vinogradow, de l'Académie, le 16. IX. 1939)

S. Cohn-Vossen a démontré le théorème suivant (1):

Deux ovaloïdes isométriques sont nécessairement congruents.

M. M. Hopf et Samelson, sans changer la marche générale de la démonstration de Cohn-Vossen, en ont simplifié la partie la plus difficile (2).

Le but du présent article est le même que celui de l'ouvrage de M. M. Hopf et Samelson. Mais la méthode que j'emploie me semble plus élémentaire et plus directe; de plus, elle est évidemment applicable à une classe assez etendue de questions analogues.

Il suffit de quelques lignes pour donner une idée de la démonstration de Cohn-Vossen. En supposant les points correspondants des ovaloïdes isométriques S, S' rapportés aux même points du plan des paramètres u, v, on aura

$$E=E', \quad F=F', \quad G=G'.$$

Par rapport aux différences

$$L'-L=\lambda, \quad M'-M=\mu, \quad N'-N=\nu$$

deux hypothèses sont possibles:

a) Elles sont nulles pour tout couple de points correspondants. Alors, d'après le théorème de Bonnet, les ovaloïdes S, S' sont congruents.

b) Elles ne s'annulent pas simultanément au moins pour un couple de points correspondants. Dans ce cas on vérifie aisément que l'équation

$$\lambda du^2+2\mu\, du\, dv+\nu dv^2=0 \qquad (1)$$

détermine, sur chacun des ovaloïdes S, S', deux champs réels de directions (directions caractéristiques), à l'exception des points où l'on a

$$\lambda=\mu=\nu=0$$

(points de congruence).

On démontre ensuite les théorèmes suivants:

A) Les points de congruence sont isolés;

B) Pour tout point de congruence l'indice de Poincaré par rapport à chacun des deux champs de directions est négatif ou nul.

La démonstration se termine en remarquant que, d'après un théorème de Poincaré, la somme des indices des points singuliers supposés isolés,

d'un champ de directions sur une surface fermée de genre zéro, est toujours égale à 4. Ceci démontre l'impossibilité de l'hypothèse b).

C'est une démonstration nouvelle des théorèmes A) et B), dans l'hypothèse b), qui fait l'objet de l'article présent.

Retranchons les équations de Gauss et de Codazzi pour l'ovaloïde S des équations analogues pour l'ovaloïde S'. En tenant compte des relations

$$L' = L + \lambda, \quad M' = M + \mu, \quad N' = N + \nu$$

on obtient

$$N\lambda + L\nu - 2M\mu + \lambda\nu - \mu^2 = 0$$

$$\left.\begin{aligned} \frac{\partial \lambda}{\partial v} - \frac{\partial \mu}{\partial u} - \left\{ \begin{matrix} 12 \\ 1 \end{matrix} \right\} \lambda + \left[\left\{ \begin{matrix} 11 \\ 1 \end{matrix} \right\} - \left\{ \begin{matrix} 12 \\ 2 \end{matrix} \right\} \right] \mu + \left\{ \begin{matrix} 11 \\ 2 \end{matrix} \right\} \nu = 0 \\ \frac{\partial \mu}{\partial v} - \frac{\partial \nu}{\partial u} - \left\{ \begin{matrix} 22 \\ 1 \end{matrix} \right\} \lambda + \left[\left\{ \begin{matrix} 12 \\ 1 \end{matrix} \right\} - \left\{ \begin{matrix} 22 \\ 2 \end{matrix} \right\} \right] \mu + \left\{ \begin{matrix} 12 \\ 2 \end{matrix} \right\} \nu = 0. \end{aligned}\right\} \quad (2)$$

Nous supposerons les ovaloïdes S, S' analytiques. Alors, si λ, μ, ν s'annulaient identiquement au voisinage d'un point (u_0, v_0), ils seraient nuls pour tout couple de points correspondants des ovaloïdes S, S', contrairement à l'hypothèse b) que nous avons admise. Donc, en tout point (u_0, v_0) on a

$$\lambda = \lambda_n + \lambda_{n+1} + \ldots, \quad \mu = \mu_n + \mu_{n+1} + \ldots, \quad \nu = \nu_n + \nu_{n+1} + \ldots$$

où λ_k, μ_k, ν_k désignent des formes de degré k en $u - u_0$, $v - v_0$, les formes λ_n, μ_n, ν_n n'étant pas identiquement nulles simultanément. Pour simplifier l'écriture nous poserons $u_0 = v_0 = 0$.

Les équations (2) pour λ, μ, ν entraînent pour λ_n, μ_n, ν_n des équations plus simples

$$N_0\lambda_n + L_0\nu_n - 2M_0\mu_n = 0, \quad \frac{\partial \lambda_n}{\partial v} - \frac{\partial \mu_n}{\partial u} = 0, \quad \frac{\partial \mu_n}{\partial v} - \frac{\partial \nu_n}{\partial u} = 0 \quad (3)$$

où L_0, M_0, N_0 désignent les valeurs de L, M, N au point (0, 0).

La forme (L_0, M_0, N_0) étant définie, on peut par une transformation linéaire réelle faire $L_0 = N_0$, $M_0 = 0$. Alors les équations (3) prendront la forme

$$\lambda_n + \nu_n = 0, \quad \frac{\partial \mu_n}{\partial u} = \frac{\partial \lambda_n}{\partial v}, \quad \frac{\partial \lambda_n}{\partial u} = -\frac{\partial \mu_n}{\partial v}.$$

Donc, la fonction $w = \mu_n + i\lambda_n$ de la variable $u + iv$ satisfait aux conditions de Cauchy-Riemann. Comme cette fonction est une forme de degré n en u, v, on a simplement

$$w = cz^n \quad (4)$$

où c est une constante. En choisissant convenablement la transformation linéaire ci-dessus, on peut d'ailleurs faire $c = 1$.

Supposons maintenant que le point (0, 0) est un point de congruence, c'est-à-dire qu'on a $n \geqslant 1$, et démontrons les théorèmes A) et B). On a le développement

$$\lambda\nu - \mu^2 = (\lambda_n\nu_n - \mu_n^2) + \ldots$$

Mais, en vertu de (4)

$$\lambda_n = -\nu_n = I(z^n), \quad \mu_n = R(z^n),$$

d'où l'on obtient

$$\lambda_n\nu_n - \mu_n^2 = -|z|^{2n}.$$

Donc, au voisinage du point (0, 0) le premier membre du développement de $\lambda\nu - \mu^2$ ne s'annule que pour le point (0, 0) lui-même. Le point singulier (0, 0) est donc isolé, ce qui est le théorème A).

Considérons les champs de directions déterminés par l'équation

$$\lambda_n du^2 + 2\mu_n du\, dv + \nu_n dv^2 = 0. \tag{5}$$

Dans un voisinage suffisamment petit de (0, 0) les champs (5) diffèrent des champs (1) aussi peu que l'on voudra. Les indices du point (0, 0) par rapport aux deux couples de champs sont donc les mêmes. Or, les indices par rapport aux champs (5) se déterminent facilement. En vertu de (4) on peut donner à l'équation (5) la forme

$$I(z^n dz^2) = 0,$$

ou

$$z^n dz^2 - \bar{z}^n d\bar{z}^2 = 0,$$

ou

$$z^{\frac{n}{2}} dz \mp \bar{z}^{\frac{n}{2}} d\bar{z} = 0.$$

Soient α et Θ les angles que l'élément dz et le rayon vecteur z forment avec l'axe u. On a (en prenant le signe supérieur dans la dernière équation)

$$\alpha = \frac{1}{2} \operatorname{Arg} \frac{dz}{d\bar{z}} = \frac{1}{2} \operatorname{Arg} \left(\frac{\bar{z}}{z} \right)^{\frac{n}{2}} = -\frac{n}{2} \frac{1}{2} \operatorname{Arg} \left(\frac{z}{\bar{z}} \right) = -\frac{n}{2} \Theta.$$

À un accroissement de 2π de l'angle Θ il correspond donc un accroissement de $-n\pi$ de l'angle α. Donc, l'indice est égal à $-n$ (il en est de même pour le champ qui correspond aux signes inférieurs; ceci revient à ajouter à α la constante $\frac{\pi}{2}$). On voit que l'indice cherché est toujours négatif, ce qui entraîne le théorème B).

On sait que deux surfaces ouvertes de courbure positive peuvent être isométriques sans être congruentes. Dans ce cas les points de congruence peuvent bien exister. On peut ce faire une idée claire des familles de courbes intégrales de (1) (lignes caractéristiques) au voisinage d'un point de congruence en intégrant l'équation approchée (5). On obtient les deux familles

$$z^{\frac{n+3}{2}} \pm \bar{z}^{\frac{n+3}{2}} = c$$

ou

$$R(z^{\frac{n+3}{2}}) = a, \quad I(z^{\frac{n+3}{2}}) = b,$$

qui sont bien connues.

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LITTÉRATURE CITÉE

[1] S. Cohn-Vossen, Gott. Nachr., 125—134 (1927). [2] Hopf u. Samelson, Math. ZS., 43, 5 (1938).

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MATHÉMATIQUES

SUR LE PROBLÈME DU CYLINDRE FLOTTANT

Par A. N. RUBAN

(Présenté par I. M. Vinogradow, de l'Académie, le 16. IX. 1939)

Un cylindre droit homogène flotte de telle manière que ces génératrices sont parallèles à la surface du liquide. On demande la forme de la base nécessaire pour que le cylindre puisse flotter en équilibre quelle que soit sa position.

Ce problème se ramène au suivant: trouver toutes les courbes planes telles que tout arc de longueur donnée l soit sous-tendu par une corde de longueur fixe b, l et b satisfaisant à la seule condition $\frac{l}{b} \geqslant 1$.

Dans la suite nous ne considérons que des courbes ainsi définies; nous les appelons simplement des courbes.

Soit $\bar{r} = \bar{r}(s)$ l'équation d'une «courbe» dans la notation vectorielle, s désignant l'arc. Nous supposerons que $\bar{r}(s)$ admet des dérivées secondes continues. En désignant par $\bar{b}$ le vecteur qui joint le point $\bar{r}(s)$ au point $\bar{r}(s+l)$, nous pouvons écrire

$$b^2 = \bar{b}^2 = [\bar{r}(s+l) - \bar{r}(s)].$$

En différentiant par rapport à s, on obtient (1) ou (2) (v. le texte russe).

Nous nous bornerons à la considération des courbes convexes. Alors la condition (2) signifie que les directions positives des tangentes aux points s et $s+l$ ont une même inclinaison par rapport à la direction du vecteur $\bar{b}$. Nous prendrons toujours pour déterminer les angles leurs valeurs positives minimes.

En différentiant (1) par rapport à s on obtient l'équation

$$[\bar{r}'(s+l) - \bar{r}'(s)]^2 + [\bar{r}(s+l) - \bar{r}(s)][\bar{r}''(s+l) - \bar{r}''(s)] = 0$$

à laquelle on peut donner la forme (3) en désignant par $2\Theta(s)$ l'angle des directions positives des tangentes aux points s et $s+l$, par $k(s)$ la courbure au point s et par $\bar{n}(s)$ la normale en ce point. Comme

$$\bar{b}\bar{n}(s) = b \sin \Theta(s), \quad \bar{b}\bar{n}(s+l) = -b \sin \Theta(s)$$

on peut donner à (3) la forme

$$4 \sin^2 \Theta(s) = b\,[k(s+l) + k(s)] \sin \Theta(s)$$

ou bien la forme (4). Nos courbes étant convexes, on a toujours $\sin\Theta(s)\neq 0$. Donc, la condition (4) se réduit à l'équation fonctionnelle (5).

Nous démontrerons maintenant quelques propriétés des courbes considérées.

1. Les courbes dont la courbure a la forme (6) sont des cercles (S désigne la longueur totale de la courbe).

Démonstration. Considérons les deux fonctions (7) et (8) de la variable complexe z. Pour tout point du cercle $|z|=1$ on a les équations (9) et (10). Pour ces points l'équation (5) entraîne l'équation (11). Mais, les fonctions $k_1(s)$, $k_2(s)$ étant analytiques, on voit que l'équation (11) a lieu pour tout le plan de la variable complexe. Montrons que l'une au moins des fonctions $k_1(z)$, $k_2(z)$ doit se réduire à une constante. En effet, admettons qu'il n'en est pas ainsi; alors les constantes a_n, b_n ne s'annulent pas simultanément. Soit $\alpha_n (n=1,2,\ldots)$ une suite de nombres réels tendant vers ∞. Soit z_n une racine de l'équation $k_2(z_n)=\alpha_n$ (qui se ramène à une équation algébrique). La suite $\{z_n\}$ doit contenir une suite $\{z_{n_k}\}$ qui tend vers 0 ou ∞. Dans le cas contraire $|z_n|$ et $|z_n^{-1}|$ seraient bornés; mais l'expression (8) montre que $k_2(z_n)=\alpha_n$ le serait alors aussi, ce qui est contraire à l'hypothèse. Les coefficients de z^h et de z^{-h} ne pouvant s'annuler que simultanément, $k_1(z_{n_k})$ doit tendre vers ∞. Mais ceci est incompatible aves (9), le sinus d'un arc réel étant borné. On a donc $k_1(z)=\text{const}$ ou $k_2(z)=\text{const}$. Mais l'équation (11) montre que pour $k_1(s)=\text{const}$ on a $k_2(s)=\text{const}$, et réciproquement. Or, de l'équation (10) différentiée par rapport à s dès (11) on tire $k(s)=\text{const}$, ce qui démontre la proposition.

2. Les cercles sont les seules courbes pour lesquelles on a $\frac{l}{S}=\frac{1}{2}$. En effet, on tire de (5)

$$\sin\Theta(s+l)=\frac{b}{4}[k(s+2l)+k(s+l)]=\frac{b}{4}[k(s)+k(s+l)]=\sin\Theta(s)\,,$$

ce qui donne l'équation (12).

Si l'on différentie (12) en tenant compte de l'équation évidente (13), on obtient (14). En tenant compte de (13) et (14) on tire de l'équation (5)

$$k(s)=\frac{2}{b}\sin\Theta(s).$$

Or, de l'équation (13) on conclut en tenant compte de l'équation (14) que $\Theta(s)=\text{const}$.

3. Les cercles sont les seules courbes pour lesquelles on a $\frac{l}{S}=\frac{1}{4}$.

Intégrons (5) de s à $s+l$. En tenant compte de (13) on obtient (15). La courbe étant fermée, la fonction Θ satisfait à l'équation (16). D'autre part, il est évident que les points s, $s+l$, $s+2l$, $s+3l$ sont les sommets d'un losange, et la condition (2) montre que les sommes des angles $\Theta(s+l)+\Theta(s)$ et $\Theta(s+2l)+\Theta(s+3l)$ (dont les sommes avec deux angles opposés du losange sont égales à π) sont égales. En tenant compte de (16) on obtient (17). Cela étant, la différentiation de (15) donne

$$\sin\Theta(s+l)=\sin\Theta(s).$$

En vertu de (17) on a $\Theta(s)\leqslant\frac{\pi}{2}$, ce qui donne (18). La comparaison de (17) et (18) donne $\Theta(s)=\text{const}$, ce qui entraîne $\Theta'(s)=k(s+l)-k(s)=0$. Ceci et (5) donnent $k(s)=\frac{2}{b}\sin\Theta(s)=\text{const}$.

4. Si les points $s, s+l, s+2l, \ldots, s+kl, s$ (k impair) sont les sommets d'un polygone dont les angles restent constants lorsque le point s décrit la courbe, cette courbe est nécessairement un cercle.

Démonstration. L'équation (2) montre que l'angle que la direction positive de la tangente au point s forme avec le côté $(s, s+l)$ du polygone est égal à $\Theta(s)$.

Montrons que cet angle est constant. En effet, en considérant les angles au point $s+l$ on voit que la somme des angles $\Theta(s)$, $\Theta(s+l)$ et de l'angle correspondant du polygone est égale à π. L'angle du polygone étant constant par hypothèse, il en est donc de même de la somme $\Theta(s)+\Theta(s+l)$. On en tire, pour une variation quelconque de s, $\Delta\Theta(s)=$ $=-\Delta\Theta(s+l)=\Delta\Theta(s+2l)=-\Delta\Theta(s)$, ce qui donne $\Delta\Theta(s)=0$, ou $\Theta(s)=$ $=$const. On en conclut, comme plus haut, que $k(s)=$const.

5. Désignons par Θ_0 et k_0 les valeurs de $\Theta(s)$ et $k(s)$ pour un cercle de longueur S. Soit $\frac{p}{S}=\frac{p}{q}$, où p et q sont des entiers positifs, et soit $\Theta_0 \operatorname{ctg}\Theta_0 \neq \frac{\pi nl}{S}\operatorname{ctg}\frac{\pi nl}{S}$ pour $n=1,2\ldots$ Alors il existe un nombre $\varepsilon>0$ tel que l'inégalité

$$|k(s)-k_0|<\varepsilon$$

entraîne l'égalité

$$k(s)=k_0.$$

Nous donnons ce résultat sans démonstration.

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MATHÉMATIQUES

SUR LE PROBLÈME DU CYLINDRE FLOTTANT

Par V. SALGALLER et P. KOSTELIANETZ

(Présenté par I. M. Vinogradow, de l'Académie, le 16. IX. 1939)

Un cylindre droit homogène flotte en équilibre indépendamment de l'orientation de la base, pourvu que les génératrices restent parallèles à la surface du liquide. On demande la forme de la base compatible avec ces conditions.

Le problème se ramène au suivant: trouver les courbes planes fermées dont l'aire est divisée en un rapport constant par une corde variable de longueur constante. Ce problème a été traité récemment par plusieurs géomètres. On a démontré, pour certains cas particuliers, que les seules courbes satisfaisant aux conditions posées sont les cercles.

Dans la première partie de l'article présent nous démontrons l'existence de solutions (non-convexes) qui ne sont pas des cercles. Dans la seconde partie nous donnons des démonstrations élémentaires de quelques résultats connus et de plusieurs nouveaux. Pour plus de simplicité nous employons des raisonnements infinitésimaux qu'il est facile de rendre rigoureux.

§ 1. On démontre facilement que pour toute courbe fermée rectifiable une corde variable qui sous-tend un arc de longueur constante divise l'aire en un rapport constant, et réciproquement.

Soient AB et $A'B'$ deux positions voisines de la corde. L'égalité des aires des triangles $AA'B$, $A'BB'$, qui ont un côté commun et deux côtés égaux, entraîne l'égalité des côtés restants AA', BB', et réciproquement.

Il existe des polygones équilatéraux irréguliers dont toutes les diagonales qui sous-tendent un nombre donné de côtés sont égales. Par exemple, en considérant les sommets et les milieux des côtés d'un polygone régulier comme les sommets d'un polygone nouveau, ont voit que dans ce dernier les diagonales qui sous-tendent un nombre donné impair de côtés sont toutes égales. Ces diagonales divisent l'aire d'un tel polygone dans un rapport constant.

En partant d'un polygone équilatéral irrégulier dont les diagonales qui sous-tendent la moitié des côtés sont égales, on peut construire une courbe qui satisfait aux conditions du problème posé et qui n'est pas un cercle.

Soit $AC...\ BD...$ un tel polygone (fig. 1), $AB=CD=l$ et $AC=BD$. Le quadrilatère $ACBD$ est inscriptible. Remplaçons le côté AC par l'arc AC et le côté BD par l'arc BD. Faisons le même pour tous les couples de côtés opposés. La courbe fermée obtenue satisfait aux conditions du problème pour la longueur l de la corde variable AB. En effet, l'aire $A'C...BB'$ ne change pas, quand le point A' décrit l'arc AC, parce qu'il en est évidemment

ainsi pour l'aire du segment de cercle $A'KB'$ et que les points A', B' partagent la longueur de la courbe toujours en deux parties égales.

On voit qu'il n'est pas nécessaire que le polygone soit équilatéral. Il suffit que les côtés opposés soient égaux.

La fig. 2 représente la plus simple des courbes considérées. Pour cette courbe un calcul élémentaire suffit pour vérifier que le cylindre correspondant est effectivement capable de flotter en équilibre pour toute orientation de la base (fig. 3). Soient P le centre de gravité de la portion du plan limitée par la courbe, P_1 et P_2 ceux de ces deux parties au-dessus et au-dessous du niveau du liquide. Il faut vérifier que la droite P_1PP_2 est perpendiculaire au niveau. Considérons une position arbitraire de la courbe.

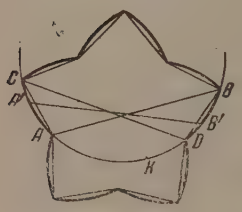

Fig. 1.

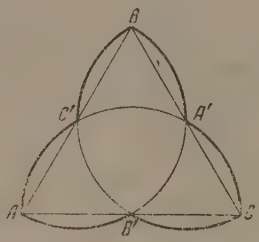

Fig. 2.

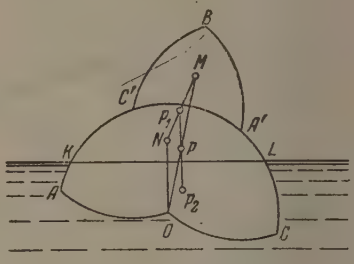

Fig. 3.

Soit M le centre de gravité de la partie $C'BA'$, N celui du segment de cercle $KC'A'L$. L'on a

$$MP_1 : NP_1 = S(KC'A'L) : S(C'BA') = \text{const};$$
$$MP : PO = \text{const}; \quad ON \perp KL.$$

Lorsque KL coïncide avec AA', le cylindre est évidemment en équilibre. L'on a

$$MP_1 : NP_1 = MP : PO.$$

Les deux rapports étant constants, il en est donc de même pour toutes les positions de la courbe. On a donc tonjours

$$PP_1 \parallel ON \perp KL.$$

Remarquons que dans tous les exemples considérés la courbe n'est pas convexe et possède des points singuliers.

§ 2. Montrons que toute courbe convexe qui satisfait aux conditions du problème a nécessairement une tangente unique en chacun de ces points.

On sait que pour les courbes convexes les seuls points singuliers possibles sont les points anguleux; on a donc toujours deux demi-droites tangentes. Or, pour une courbe qui satisfait aux conditions de notre problème on démontre facilement, par un déplacement infinitésimal de la corde AB, que les demi-droites tangentes aux points A, B situées de part et d'autre de la droite AB, forment avec la corde AB des angles complémentaires. On voit donc que l'existence d'un point anguleux à l'une des extrémités de la corde AB entraîne l'existence d'une concavité à l'autre extrémité.

Dans la suite nous ne considérons que les courbes régulières.

Si l'angle de la corde AB et de la tangente en A ne change pas lorsque A décrit la courbe, celle-ci est un cercle (fig. 4). On s'en assure en démon-

trant que la courbure existe en chaque point et qu'elle est constante (v. le calcul dans le texte russe).

Les résultats obtenus permettent de donner une démonstration élémentaire des théorèmes suivants (dont le premier est connu).

a) Si trois cordes l_1, l_2, l_3 qui forment un triangle ABC (fig. 5) satisfont aux conditions de notre problème, la courbe est un cercle (2):

$$\angle 2 = \pi - \angle 1 - \varphi_1, \quad \angle 3 = \angle 1 + \varphi_1 - \varphi_2$$
$$\angle 1 = \angle 4 = \pi - \angle 1 - \varphi_1 + \varphi_2 - \varphi_3.$$

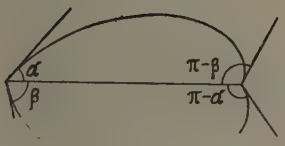

Fig. 4.

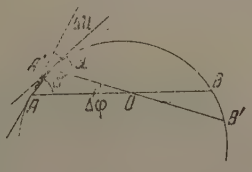

Fig. 5.

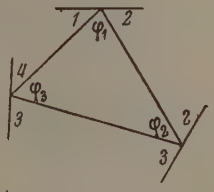

Fig. 6.

Comme on a $\varphi_1 + \varphi_2 + \varphi_3 = \pi$, on en tire

$$\angle 1 = \angle 2 = \text{const.}$$

b) Même résultat pour un quadrilatère $ABCD$ dont les côtés sont l_1, l_2, l_3, l_4 et les angles sont $\varphi_1, \varphi_2, \varphi_3, \varphi_4$.

Par un raisonnement analogue au précédent on obtient l'égalité $\varphi_1 + \varphi_3 = \varphi_2 + \varphi_4$.

Donc, le quadrilatère $ABCD$ est inscriptible. Par suite, les longueurs de ses côtés étant données, il est déterminé aux déplacements près. En considérant, par exemple, le triangle ABC, on est ramené au théorème précédent.

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MATHÉMATIQUES

SUR L'INTERPOLATION AU MOYEN DES DÉRIVÉES ET SUR LES PROCÉDÉS D'INTERPOLATION CORRESPONDANTS. I

Par I. M. KAMENETZKY

(Présenté par S. I. Wawilow, de l'Académie, le 17. VIII. 1939)

Soient données: 1) une suite d'entiers non-négatifs $n_0 \leqslant n_1 \ldots \leqslant n_m$; 2) une suite de points $x_0, x_1, \ldots x_m$ situés dans le plan de la variable complexe telle que $|x_i - x_j| + |n_i - n_j| \neq 0$ pour $i \neq j$ $(i, j = 0, 1, \ldots m)$; 3) une suite de nombres $c_0, c_1, \ldots c_m$.

Théorème I. *Pour que le problème de la construction d'un polynôme $f_m(x)$ de degré inférieur ou égal à m et vérifiant les conditions*

$$f_m^{(n_i)}(x_i) = c_i \qquad (i = 0, 1, \ldots m)$$

possède une et une seule solution quelle que soit la situation des points x_i $(i = 0, 1, \ldots, m)$ dans le plan complexe, il faut et il suffit que la suite n_i $(i = 0, 1, \ldots, m)$ vérifie les conditions suivantes

$$n_i \leqslant i \qquad (i = 0, 1, \ldots, m); \tag{a}$$

il existe pour chaque i un certain j $(i, j = 0, 1, \ldots, m)$ tel que

$$n_i = n_j = j. \tag{b}$$

Définition. Une suite d'entiers $n_0 \leqslant n_1 \ldots \leqslant n_m$ non-négatifs et vérifiant les conditions a) et b) sera nommée graduée.

Une suite infinie d'entiers non-négatifs $n_0 \leqslant n_1 \ldots$, telle que chacune de ces suites partielles $n_0, n_1, \ldots, n_m$ $(m = 0, 1, \ldots)$ est aussi graduée, sera de même nommée graduée.

Soit: 1) $f(x)$ une fonction réelle de la variable x possédant sur le segment $[a, b]$ de l'axe réel des dérivées continues jusqu'à l'ordre $m+1$; 2) $n_0, n_1, \ldots n_m$ — une suite graduée: 3) x_i $(i = 0, 1, \ldots m)$ — une certaine suite de points situés sur le segment $[a, b]$ et vérifiant la condition 2) du théorème I; 4) $f_m(x)$ — un polynôme de degré m au plus, vérifiant les conditions

$$f_m^{(n_i)}(x_i) = f^{(n_i)}(x_i) \qquad (i = 0, 1, \ldots m),$$

qui existe d'après le théorème I et qui est déterminé d'une manière unique par ces conditions. Désignons la différence $f(x) - f_m(x)$ par $R_m(x)$.

Théorème II. *La fonction* $R_m(x)$ *peut être présentée dans la forme*

$$R_m(x) = \int_{\eta_0}^{x} dx' \int_{\eta_1}^{x} dx'' \ldots \int_{\eta_m}^{x^{(m)}} f^{(m+1)}(x^{(m+1)})\, dx^{(m+1)},$$

où η_i $(i=0, 1, \ldots m)$ *sont des nombres réels dépendant de* f *et des* x_i $(i=0, 1, \ldots m)$ *et vérifiant les inégalités* $a \leqslant \eta_i \leqslant b$. *On a d'ailleurs l'inégalité*

$$|R_m(x)| \leqslant \frac{M_{m+1}}{(m+1)!}(|x-x_0|+s_m)^{m+1},$$

où M_{m+1} *est le maximum du module de* $f^{(m+1)}(x)$ *sur le segment* $[a, b]$ *et* $s_m = \sum_{i=1}^{m} |x_{i-1}-x_i|$.

Définitions. Soit: 1) n_i $(i=0, 1, \ldots)$ — une suite infinie graduée; 2) x_i $(i=0, 1, \ldots)$ — une suite de points sur le plan de la variable complexe telle que chacune des suites $x_0, x_1, \ldots x_m$ $(m=0, 1, \ldots)$ vérifie la condition 2) du théorème I; 3) $f(x)$ — une fonction qui admet les dérivées de tous les ordres aux points x_i $(i=0, 1, \ldots)$.

Une suite de polynômes de degré au plus égal à m, soit $f_m(x)$ $(m=0, 1, \ldots)$, vérifiant les conditions

$$f_m^{(n_i)}(x_i) = f^{(n_i)}(x_i) \qquad (i=0, 1, \ldots m)$$

sera nommée procédé d'interpolation (P_{n_i}) pour la fonction $f(x)$ associé à la suite des points $\{x_i\}$. Comme cas particuliers, pour $n_i=0$ et $n_i=i$ on obtient les procédés d'interpolation de Newton et d'Abel [1].

Si pour les points d'un certain ensemble M on a la relation

$$\lim_{m\to\infty} f_m(x) = f(x),$$

nous dirons que pour la fonction $f(x)$ le procédé d'interpolation (P_{n_i}) associé à la suite des points $\{x_i\}$ converge sur l'ensemble M.

Les polynômes $f_m(x)$ $(m=0, 1, \ldots)$, qui figurent dans les définitions précédentes, seront nommés polynômes d'interpolation pour la fonction $f(x)$ associés au procédé d'interpolation (P_{n_i}) et à la suite des points $\{x_i\}$.

Théorème III. *Soit*: 1) n_i $(i=0, 1, \ldots)$ — *une suite infinie graduée;* 2) x_i $(i=0, 1, \ldots)$ — *une suite de points situés sur une droite et convergeant vers un point* X *de telle manière que la série* $\sum_{i=1}^{\infty} (x_{i-1}-x_i)$ *soit absolument convergente et que* $|x_i-x_j|+|n_i-n_j| \neq 0$ $(i \neq j;\ i, j=0, 1, \ldots)$. *Alors le procédé d'interpolation* (P_{n_i}), *associé à la suite des points* $\{x_i\}$, *converge pour chaque fonction* $f(x)$, *analytique dans un cercle de centre* X *et contenant tous les points de la suite* $\{x_i\}$, *la convergence étant garantie dans un cercle de centre* X *et de rayon* $\frac{R}{2}$, *où* R *est le rayon de convergence de la série potentielle de* $f(x)$ *au point* X.

Ce théorème est une généralisation partielle du théorème correspondant de V. Gontcharoff concernant la convergence des séries généralisées d'Abel [1].

Conséquence du théorème III. Si les conditions 1) et 2) du théorème précédent sont vérifiées et si tous les nombres $f^{(n_i)}(x_i)$ $(i=0, 1, \ldots)$, où $f(x)$ est une fonction holomorphe au point X, sont nuls, on a $f(x) \equiv 0$. En particulier, si $f(x)$ est une fonction entière non identiquement nulle, la série $\sum_{i=1}^{\infty} |x_{i-1} - x_i|$ ne peut être convergente, si $f^{(n_i)}(x_i) = 0$ $(i=0, 1, \ldots)$.

Théorème IV. *Soit:* 1) n_i $(i=0, 1, \ldots)$ — *une certaine suite infinie graduée;* 2) x_i $(i=0, 1, \ldots)$ — *une suite de points situés sur le segment* $[-1, +1]$ *de l'axe réel et telle que* $|x_i - x_j| + |n_i - n_j| \neq 0$ $(i \neq j;\ i, j = 0, 1, \ldots)$. *Alors le procédé d'interpolation* (P_{n_i}) *associé à la suite* $\{x_i\}$ *converge pour toutes les fonctions entières de classe* $< \left[1, \frac{\pi}{4}\right]$ (2).

La constante $\frac{\pi}{4}$ est exacte, ce que l'on voit en considérant l'exemple: $n_i = i$, $x_i = (-1)^{n+1}$, $f(x) = \sin \frac{\pi}{4}(x+1)$.

Ce théorème est une généralisation du théorème de Schoenberg sur la convergence de la série généralisée d'Abel (3).

Conséquence du théorème IV. Si les conditions 1) et 2) du théorème IV sont vérifiées et si $f(x)$ est une fonction entière de classe $< \left[1, \frac{\pi}{4}\right]$, dans le cas où $f^{(n_i)}(x_i) = 0$, on a $f(x) \equiv 0$.

Université d'Etat à Voronège.

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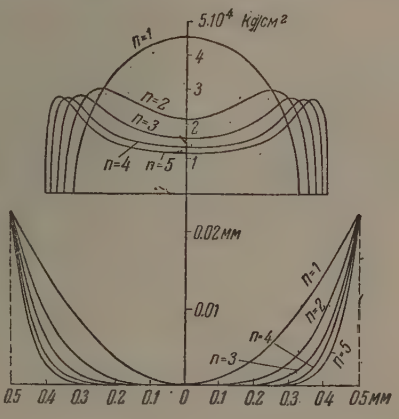
THEORY OF ELASTICITY

TO HERTZ'S THEORY OF LOCAL DEFORMATIONS IN COMPRESSED ELASTIC BODIES

By E. STEUERMANN

(Communicated by S. L. Sobolev, Member of the Academy, 26. IX. 1939)

The solution of the problem on local deformations and stresses in compressed elastic bodies given by Hertz involves a series of essential limitations. In particular, it is supposed that the original distance $l\ (x, y)$ between points of the surfaces of compressed bodies touching one another at the origin may be approximated on the ground of smallness of the dimensions of the pressure surface by the sum of terms of the second degrees and the development of the function $l\ (x, y)$ into a power series. Thus, Hertz's solution cannot be applied in the case when the second derivatives of the function $l\ (x, y)$ vanish at the origin. We solve the problem on local deformations in elastically compressed bodies under more general assumptions in the case of bodies of rotation, whose axes coincide with the line of action of compressing forces, as well as for the case of cylindrical bodies (the plane problem). From the solution obtained by us follows that the diagram of distribution of stresses is rather sensitive to the change of the curve of distances between compressed bodies. As may be seen from Fig. 1, the maximum stress, particularly important for technical calculations, moves from the centre of the pressure surface to its boundary, when the degree of the parabolic curve representing the curve of distances between compressed bodies is increased.



In the case of bodies of rotation the length depends only on the distance r from the origin. Suppose that all derivatives of the function l with respect to the argument r up to the $(2n-1)$-st inclusively vanish for $r=0$. In this case the radius of the pressure surface p and the pressure $p(r')$ at the point of the pressure surface, removed by r' from the line of action of compressing forces, are determined by the following integral equation:

$$(\vartheta_1+\vartheta_2)\int_0^{2\pi}\int_0^{p} p(r')\left(\frac{1}{r'}-\frac{1}{\sqrt{r^2-2rr'\cos\varphi+r'^2}}\right)r'\,dr'\,d\varphi = Ar^{2n}\quad (r\leqslant p)\qquad (1)$$

and the condition

$$2\pi \int_0^p p(r')\, r' dr' = P \tag{2}$$

where

$$\vartheta_1 = \frac{1-\sigma_1^2}{\pi\varepsilon_1}, \qquad \vartheta_2 = \frac{1-\sigma_2^2}{\pi\varepsilon_2}$$

ε_1, σ_1 and ε_2, σ_2 are the elastic constants of compressed bodies,

$$A = \frac{1}{n!}\left(\frac{d^n l}{dr^n}\right)_{r=0}, \qquad A > 0$$

and P is the compressing force.

Besides, the following inequality must be satisfied:

$$(\vartheta_1+\vartheta_2)\int_0^{2\pi}\int_0^p p(r')\left(\frac{1}{r'} - \frac{1}{\sqrt{r^2 - 2rr'\cos\varphi + r'^2}}\right) r' dr' d\varphi < Ar^{2n} \quad (r > p). \tag{3}$$

The solution of the integral equation (1) has the form:

$$p(r') = \frac{Ap^{2n-1}}{\pi^2(\vartheta_1+\vartheta_2)}\left[\frac{2\cdot 4\ldots 2n}{1\cdot 3\ldots(2n-1)}\right]^2 p_n\left(\frac{r'}{p}\right) \tag{4}$$

where

$$p_n(t) = n\left[t^{2n-2} + \frac{1}{2}t^{2n-4} + \ldots + \frac{1\cdot 3\ldots(2n-3)}{2\cdot 4\ldots(2n-2)}\right]\sqrt{1-t^2}; \tag{5}$$

this may be verified by direct substitution of the function $p(r')$ from (4) into (1).

Substituting the function $p(r')$ from (4) into (3), we find that the inequality (3) is also satisfied.

Substituting (4) into (2), we obtain the radius of the pressure surface p:

$$p = \sqrt[2n+1]{\frac{2n+1}{2n}\,\frac{1\cdot 3\ldots(2n-1)}{2\cdot 4\ldots 2n}\,\frac{\pi(\vartheta_1+\vartheta_2)P}{2A}}. \tag{6}$$

Further we find the approachment α of the compressed bodies:

$$\alpha = 2\pi(\vartheta_1+\vartheta_2)\int_0^p p(r')\,dr' = \frac{2\cdot 4\ldots 2n}{1\cdot 3\ldots(2n-1)}\,Ap^{2n}. \tag{7}$$

In Fig. 1 are shown the graphs of the functions $p_n(t)$ characterizing the distribution of pressures over the pressure surface for values of n from 1 to 5. Only for the case $n=1$ (the case considered by Hertz) the pressure attains its maximum at the centre of the pressure surface: for $n>1$ the pressure attains ist maximum on the circumference

$$r' = t_n p, \tag{8}$$

where t_n is the root of the equation

$$t^{2n-2} - \frac{1}{2}t^{2n-4} - \frac{1}{2\cdot 4}t^{2n-6} - \ldots - \frac{1\cdot 3\ldots(2n-5)}{2\cdot 4\ldots(2n-2)} = 0 \tag{9}$$

situated in the interval $(0, 1)$.

In the plane problem l depends only on the distance x to the plane in which the compressing forces act. If all the derivatives of the function l with respect to x up to the $(2a-1)$-st inclusively vanish for $x=0$,

then the half-breadth of the pressure surface a and the pressure $p(x')$ at the point of the pressure surface, removed by x' from the plane in which the compressing forces act, are determined by the integral equation

$$2(\vartheta_1+\vartheta_2)\int_{-a}^{+a} p(x')\ln\left|\frac{x-x'}{x'}\right|dx' = Ax^{2n}, \qquad (|x|\leqslant a) \tag{10}$$

and the condition

$$\int_{-a}^{+a} p(x')\,dx' = P \tag{11}$$

where

$$A=\frac{1}{n!}\left(\frac{d^n l}{dx^n}\right)_{x=0}, \qquad A>0$$

and P is the compressing force per unit of length of the generatrix of the compressed cylinders.

Besides, the following inequality must be satisfied:

$$2(\vartheta_1+\vartheta_2)\int_{-a}^{+a} p(x')\ln\left|\frac{x-x'}{x'}\right|dx' < Ax^{2n}, \qquad (|x|>a). \tag{12}$$

In this case

$$p(x')=\frac{nAa^{2n-1}}{\pi(\vartheta_1+\vartheta_2)}\,p_n\left(\frac{x'}{a}\right), \qquad a=\sqrt[2n]{\frac{2\cdot 4\ldots 2n}{1\cdot 3\ldots(2n-1)}\,\frac{(\vartheta_1+\vartheta_2)P}{nA}}.$$

The character of the variation of the distribution of pressure over the pressure surface with increasing n remains in this case the same as in the case of compression of bodies symmetrical with respect to the line of action of compressing forces.

From the solution of the equation (1) we may pass to the solution of the equation, the right-hand side of which is a polynomial in r.

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ASTRONOMY

ROTATION OF SOLAR CORONA AS DETERMINED FROM THE APPARENT DISPLACEMENTS IN ITS STRUCTURE

By S. K. VSESVIATSKY and E. J. BUGOSLAVSKAJA

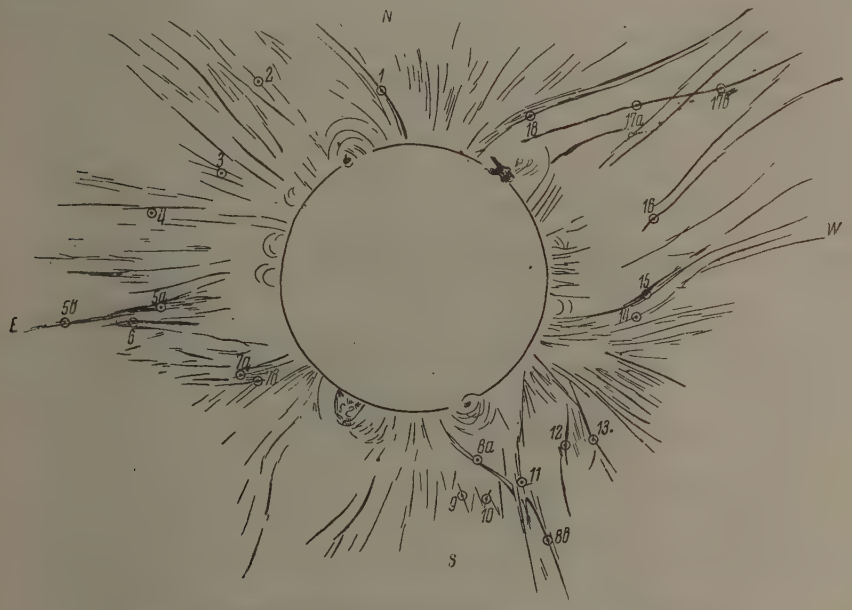
(Communicated by V. G. Fessenkov, Member of the Academy, 16. IX. 1939)

The valuable observations secured by the Soviet expeditions with standard coronographs during the total solar eclipse of June 19, 1936, permitted to investigate the changes in solar corona which took place, while the shadow of the moon was passing during two hours from the North Caucasus to the Far East. Six standard coronographs ($f=5$ m) were mounted along the belt of totality. In the total 30 photographs of the inner and outer corona were taken at four cities: Beloretchenskaya, the Ural River, Omsk and Kuybyshevka (Far East). At two cities, namely at the Krasnoyarsk district and at Khabarovsk, the observations failed, as in the phase of totality the Sun was hidden behind the clouds. The plates of the corona being taken with standard instruments of the same type, it proved possible to compare with high accuracy the position of coronal formations, to measure their displacements, to examine qualitative changes in them. The preliminary results obtained were published in the reports of Soviet expeditions (vol. 1). It proved possible to measure with fair accuracy the displacement of individual rays in the outer corona and the borders of powerful formations which we have called «fans». In particular, it was found possible to use the standard coronograph plates for solving the problem of the rotation of the corona. Up to the present time this problem has not been ultimately settled, and numerous investigators were of the opinion that the participation of the corona, if any, in the rotation of the Sun is quite negligible. Owing to great difficulties and systematical errors, early determinations of radial velocities showed the difference between the radial velocities of the east and west limbs to be less than it should be if the corona rotated with the Sun. The latest papers by Lyot (B.S.A.T., 1937, May) gave a full agreement of the difference of radial velocities between the east and west limb with the value required when assuming, that the inner corona rotates together with the Sun. All the previous attempts to determine the displacements in the solar corona during the eclipses of 1918, 1923 and 1926 being rather uncertain, could be of no use for solving the problem in question.

Having at our disposal a unique material most suitable for accurate measurements, we were able to set this problem and, as it appears, have succeeded in solving it. The comparative measurements of different epoch plates were made with a Pulkovo blink-comparator. After orientating the plates, the displacements of rays, borders of fans and contours of individual

details were measured on the photographs in x or y axes. These measurements were corrected for the difference in refraction, for the instrumental errors of the blink-comparator, for the difference in scales of the plates and the error of plate orientation (the difference in scales not exceeding 0.02 mm per 1 cm). In all 9 pairs of plates of the inner and outer corona with the difference of $1^h\ 20^m$—$1^h\ 56^m$ between the times of exposures were examined, each pair being measured by two or three measurers. The accuracy of measurement of a single displacement turned out to be ± 0.05 mm for each measurer, which corresponds to $\pm 2''$ or ± 0.3 km/sec. for Ural-Kuybyshevka pairs.

A comparison of measurements for individual pairs and individual measurers has shown the results to be reliable.



Schematic drawing of the corona obtained at Kuybyshevka.

To solve the problem of the rotation of solar corona 18 brightest and most distinct details were selected. All the measurements referring to the same detail were combined into one or two normal places. Whence the angular displacements of details for a normal place were determined as a whole (i. e. the changes in its position angle)

$$\Delta\eta = \frac{\Delta y \sin\psi}{\rho \sin 1'} = \frac{\Delta x \cos\psi}{\rho \sin 1'}$$

where ψ and ρ are the polar co-ordinates of the point under consideration.

It is self-evident that when the corona rotates with the Sun as a whole, the rotation of a detail and the change of its position angle depend on the heliographic co-ordinates of the base of the detail and on the velocity of the Sun's rotation.

As the first approximation we have adopted that the coronal rays, borders, etc. are directed radially to the Sun's surface. In some individual rays the non-radiality of the direction of details was accounted for. The measurements permitted to establish the doubtless presence of displacements having opposite directions with different details of the corona. Therefore

	Coronal formation	Polar co-ordinates of the normal place		Measured displacement for 2 hours	Number of pairs	Number of measurements
		ρ	η			
1	North-East fan	1.40	13°	$\Delta x + 0.28$	9	122
2	Straight ray in North-East fan	1.84	37	$\Delta x - 0.62$	6	22
3	Ray in North-East interspace	1.62	64.5	$\Delta y + 1.08$	5	12
4	Next straight ray to the East	1.95	79	$\Delta y + 1.39$	4	16
5a	Large East ray	2.60	104	$\Delta y + 2.69$	7	71
5b	» » »	2.00	103	$\Delta y + 1.45$	9	54
6	South component of the large East ray	2.14	106	$\Delta y + 0.78$	3	4
7a	Rays in the South-East gap .	1.43	125	$\Delta y + 0.05$ or 0.03 (weighed)	5	9
7b	Straight ray in the South-East gap	1.41	127	$\Delta y - 0.18$	2	4
8a	South-East fan (border) . . .	1.47	202	$\Delta x - 0.18$	8	71
8b	Ibid.	2.25	210	$\Delta x + 0.03$	4	40
9	South polar region (border) .	1.63	199	$\Delta x + 0.93$	2	4
10	System of faint helmets «Comb»	1.75	204	$\Delta x - 2.67$ $- 2.74$ (weighed)	3	15
11	Western border of helmets overlapping the South-West fan	1.61	214	$\Delta x + 1.06$	5	16
12a	Western border of the South-West fan	1.66	229	$\Delta x - 1.22$	7	40
12b	Ibid.		—	$\Delta x - 3.57$	1	6
13	Fainter border of the South-West fan	1.72	234	$\Delta x + 1.23$	4	18
14	Western projection; bright border	1.70	270	$\Delta y - 0.74$	9	29
15	Ibid., dark border	1.70	270	$\Delta y - 1.54$	9	50
16	North-East fan; south border	1.84	286	$\Delta y - 0.73$	6	20
17a	North-West fan; the north border of long helmets	2.16	311	$\Delta y - 0.68$ $- 1.19$ (weighed)	5	17
17b	Ibid.	2.72	307	$\Delta y + 1.80$	2	8
18	North-West fan; north border	1.51	329	$\Delta y - 0.16$	2	5

Note.

Measured $\Delta\eta$	Determined φ	Determined λ	Formation on Solar surface	Co-ordinates φ	Co-ordinates λ	Note
+ 5′.9	+77°	−110°	The dark filament of prominence «Little Bear»	−58°	−110°	Middle
− 8.5	+56	− 75	Bright flocculi preceding the filament «Little Bear»	+50+53	− 76	
−16.2	+21	− 56	Bright flocculi surrounding the spot	+21	− 57	
−21.3	+ 7	− 32	South part of the bright intense flocculus	+11	− 32	
−30.2	− 7	−150	Probably connected with the intense bright flocculus	−15	−140−150	
−21.2	−5−8	−160−150				
−10.8	−12−20	−130	Front part of the great flocculus	−20	—	
− 0.0	−35	− 90	Possibly connected with the bright flocculus	−30	−80−95	
+ 3.5	−34	−65−66	Do	—	—	
+ 3.5	−64	Near the edge (+90)	Dark filament of the prominence «Haystack»	−64	+ 90	
− 0.3						
−15.3	−65	+135	Dark intense flocculus; head part of the filament «Haystack»	−66	+130+135	
+44.0	−49	+ 31	Dark filament extended	−49	+ 31	
−17.1	−52−50	+120+113	Dark dense filament	−49−50	+120	
−16.1	−39	+66+68	Disturbed region; bright flocculi and dark filaments	−40−45	+60−+65	
−47.7						
+14.6	−32−35	+68+69	The same disturbed region	—	—	
—	near 0	76	Head part of the large slightly diffused dark filament	0− −5	+60+65	
—	near 0	65				
+11.5	+14	+ 55	Bright flocculus surrounding the spot; behind it dark flocculi	+20	+40−+55	
+13.5	+40	+109	Connected with the dark intense filament of prominence «Horse»	+55	+ 75−+125	Helmets not radial, inclined to the equator
+16.9	+35	+115	Head part	—	—	
− 1.7	+59	+87+85	The same filament; helmet above prominence «Horse»	—	—	

considering the observed displacements as caused by the rotation of the corona together with the Sun, it was possible to find the spatial distribution of the details. For this purpose in addition to the observed displacement $\Delta\eta$, the position angle of detail η was to be derived. In such a way the observed displacements could be compared with those obtained, which allowed to determine the heliographic co-ordinates, the given coronal formations were coming from. The theoretical angular displacement of a coronal detail whose base co-ordinates are λ and φ, ν being the angular velocity of rotation, finds its expression in the following form:

$$\Delta\eta = \nu\tau \frac{(-\cos\varphi \sin B + \sin\varphi \cos B \cos\lambda)\cos\varphi}{1-(\sin\varphi \sin B + \cos\varphi \cos B \cos\lambda)^2}$$

where B is the latitude of the Sun's disk centre, η being counted from the projection of solar rotation axis. The auxiliary tables have greatly facilitated the determination of heliographic co-ordinates of coronal details by the apparent displacements. To check our suggestions and conclusions we have used the spectroheliograms for the full revolution (½ revolution before and after the eclipse), kindly put at our disposal by the Medon and Mt-Wilson observatories. It was but natural to believe that the powerful coronal formations correspond to the excited regions of the Sun's surface. On the other hand, the application of spectroheliograms permits to find a certain conformity between the formations on the Sun's surface and the details in the corona.

The table contains the examined details, co-ordinates of normal places, their measured and angular displacements, the corresponding heliographic co-ordinates and the formations on the Sun's surface. The displacements under measurement proved to have different directions, which is in accordance with different dispositions of details. It has been proved that the displacements are due to the effect of the solar corona rotating together with the Sun. Besides fair agreement was observed between the coronal formations and those on the Sun's surface. In all cases most conspicuous coronal formations correspond to the disturbed places on the solar surface.

The group of gigantic «helmets» forming «fans» rise above the prominences corresponding to the dark flocculi on the solar surface. Straight intense rays come from the regions of bright calcium flocculi.

The velocity of rotation smaller than that adopted by us (14° a day) shows a poorer agreement with the observed displacements.

In such a way the present investigation corroborates the suggestion that the corona rotates together with the Sun. No doubt, some peculiar motions of details in the corona are possible also. The extensive East ray may serve as an example. In receding from the Sun's limb, the displacement marks in it have a velocity increasing more rapidly than it should be if its rotation was that of a solid body.

A special study of peculiar displacements will be a following step to study the movements in the outer corona.

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ASTRONOMY

THE INNER CORONA ON JUNE 19, 1936. INVESTIGATION OF CORONAL STRUCTURE AND CHANGES OCCURRING IN THE CORONA AND CHROMOSPHERE

By S. K. VSESVIATSKY and E. J. BUGOSLAVSKAJA

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The remarkable photographs of the corona on June 19, 1936, obtained with standard coronographs by the Soviet expeditions and described in our previous papers ([1], [2], [3]), provided the basis for a detailed investigation on the structure of the inner corona and chromosphere and of the changes which took place in the corona during the period of almost two hours while the photographs were made. The conclusions given below were reached as a result of discussing the numerous measurements of the shape of coronal formations, of changes occurring in the corona and chromosphere and of a comparison of the coronal photographs with the spectrograms obtained by the expedition to Ak-Bulak and with spectroheliograms and other data characterizing the Sun's surface during the period from June 12 to 25.

A characteristic feature of the coronal structure was the existence of arc systems—systems of elliptically shaped arcs encircling each other, with axes almost coincident, and which were undoubtedly due to some centre of forces situated on the Sun's surface. We could distinguish 20 arc systems; in some of them the number of arcs was over 7. In nearly every case, within the arc system, but not necessarily in the centre, there was a prominence which was undoubtedly formed by forces of the same centre or field, that had brought about the formation of the arc coronal system.

The shape of the arcs can generally be adequately represented as an ellipse, having its centre near the Sun's surface. The spread of the arcs in a given system increases with regularity from the lower arcs to higher ones; the relation between arc eccentricity and arc altitude proves to be rather definite and is expressed by the following empirically derived ratio:

$$(1-e)(\Delta+0.15)=0.091$$

where e is arc eccentricity, corrected with respect to projection and Δ—altitude of arc above Sun's surface, expressed in fractions of the Sun's radius.

The relation of arc width to altitude was also found. Displacement within arc systems appeared small, and velocities seldom reached 3 km/sec. It was noted that summits of the arcs generally ascend with a mean velocity of 0.5 km/sec., and there is some compression of the arcs at their bases at a velocity of 0.4 km/sec.

The problem of spatial arrangement of coronal formations could be conclusively solved, as well as that of their spatial structure. In every case we succeeded in distinguishing the prominences related to respective arc systems and, consequently, in correlating the arc systems themselves with the dark filaments, whose position was ascertained on spectroheliograms.

Fig. 1 shows a diagram of the corona structure with arc systems and other formations, the details being numbered according to their respective numbers in Fig. 2, where a view of the Sun's surface is given in a Simpson's projection after the spectroheliograms and other solar data. The central meridian (Fig. 2) corresponds to the moment of totality, i. e. 6^h UT June 19, 1936.

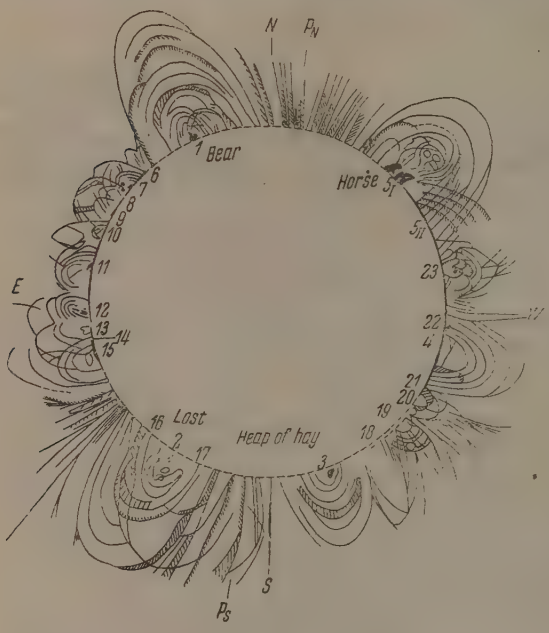

Fig. 1.

Intense arc systems in higher heliographical latitudes are involved in powerful formations extending some 30—60 degrees over the limb, and which we termed «fans». These fans represent the most impressive individual coronal formations, corresponding to areas of large excited regions in the Sun. The arc systems are enclosed within the fans, and their investigation shows that in their uppermost parts the arc systems merge into a bunch of twisted jet-like, straight and almost radial rays, many of which can be traced as far as 3 or 4 radii above the Sun's surface. The edges of the fans have a curvature and inclination corresponding to the arcs of the inner systems and seem to represent the bases of outer arcs, devoid of summits.

The fans are distinctly separated from each other and in their interspaces other characteristic coronal formations are situated—systems of coronal rays. They are schematically shown in Fig. 1. On June 19, 1936, the Northern polar ray system was the most prominent.

The rays are arranged in pairs and their shape may be studied in detail. They are curved towards the adjacent fans, which proves their connexion with the disturbed fan region. Accurate measurements of the rays' displacement have shown clearly perceptible, though often very insignificant displacements which can be very well attributed to the rotation of the corona along with the Sun. We were thus able to establish the fact that the ray systems form a kind of special network occupying the regions between the fans. Thus, the ray systems are a characteristic coronal formation corresponding to undisturbed regions of the solar surface.

We have studied in some detail the changes occurring in the prominences and chromospheres, which enabled us in many cases to obtain a clear idea of the motion within individual parts of prominences. We have often found

that individual concretions of prominences are transformed into coronal clouds. The motion of matter of the prominences along steady lines (which are evidently lines of force) towards the Sun's surface has also been studied (e. g. formation of prominences 2, 5, 12—13, 22). This shows that at a certain moment the matter of prominences appears charged and is then subject to the action of a local field of forces.

We have established the presence of peculiar coronal formations intensively emitting coronal substances. We have termed them «bushes»; three such formations were found upon the limbus of June 19 (Nos. 14, 20 and 23 in Fig. 1). It was found that these formations exactly correspond to a region of spots and bright floccules and are characteristic of the condition of the corona over these regions.

One of these formations should be especially noted—the «bomb» phenomenon in the south-western bush which ascended and then fell in the opposite direction along the same inclined trajectory—the line of current. Similar splashes and upshots of isolated chromosphere masses are a characteristic feature at the borders of bush regions.

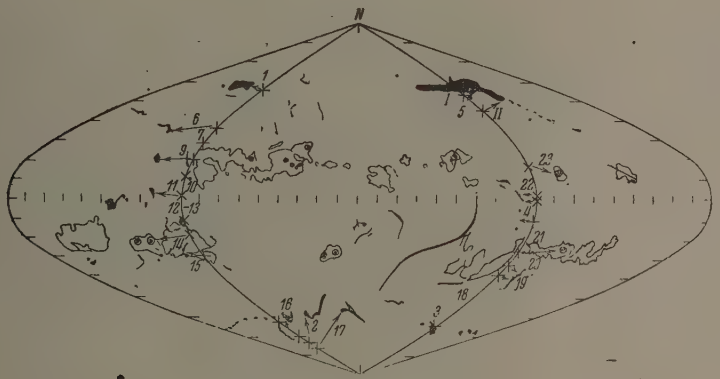

Fig. 2.

The general conclusions drawn from our investigations are as follows:

1. The phenomena observed in the chromosphere and regions overlying it are caused by centres or foci of disturbance on the Sun's surface, whose frequency and mode of distribution vary according to the phase of solar activity. The extent of field of a given centre is greater in the polar zone than in regions in the proximity of the equator, owing to a far greater frequency of distribution of active centres in the equatorial regions.

2. Coronal arc formations and fan shapes are situated over the centres of disturbance, related to dark filaments and floccules. Such a disturbance is expressed in the chromosphere by the formation of a prominence which appears enclosed within an arc system. Thus, the appearance of the corona results from peculiarities of the eruptive processes on the solar surface. This conclusion is in full agreement with the results of investigations of coronal shape with respect to the phase of solar activity. Considering that powerful coronal formations are related to the dark filaments forming the prominences, it is quite clear that during the maxima of solar activity, when these filaments rise to higher latitudes, fans also appear in high latitudes and the corona assumes a more «shaggy», less compressed shape than during the minima of activity, when the dark filaments are enclosed within a certain zone near the equator.

At the same time, the inclination of fan axes undergoes a regular variation from the period of maximum to that of minimum; measurements of photographs of 14 eclipses have shown that the fan axes are near to a line normal to the Sun's surface during the maxima and are inclined to the direction of the Sun's equator from the normal at an angle up to 35° during the minima of eruptive activity.

3. Rays are a usual feature of coronal structure in undisturbed regions; their characteristic distribution is in pairs, which is especially evident in the polar region.

4. An exhaustive discussion of the results obtained by the Soviet expeditions, as well as of those gained by a special photometrical investigation, have proved beyond any doubt that the fan shapes possess a discrete structure and represent a system of successive superimposed shell domes. The rays and arcs undoubtedly have a complex jet structure. The helmet shapes of fans point to the presence of a vortical field in certain regions of the corona.

5. The coronal processes taking place over bright floccules and groups of spots have their peculiar formations—the coronal «bush», i. e. emission of a considerable mass of coronal matter having a high percentage of free electrons, which is seen from the intense continuous spectrum in these regions. The field in the «bush» regions is evidently intense, complex and highly disturbed; this may be seen by the complexity of the bush structure as compared to other excited regions in the corona.

6. The matter forming the prominences is in some cases or in a certain phase charged and it causes the formation of coronal «shells»—the arcs over separate parts of the prominences.

7. Transformation of chromosphere substance and prominence matter into coronal state takes place by means of: a) emission through the protruding parts of the prominences and the chromosphere; b) dissolution of concretions and splashes of prominences into coronal clouds and as a result of transformation of considerable masses of prominences into coronal condition; and c) as a result of uniform and steady emission both from the excited and unexcited regions.

8. The influence of the Sun's total field is manifested: a) by the existence of the reduced luminosity of the corona which we have found throughout an equatorial zone about 17° in width and inclined to the heliographical equator at an angle of 4°; this equatorial reduction in luminosity can be well traced upon photographs of previous eclipses; and b) by peculiar inclination of fan axes with respect to normal and variations in this inclination with phases of solar activity.

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ASTRONOMY

ELEMENTS OF THE PHYSICAL THEORY OF METEORS

By B. J. LEVIN

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Collision of Meteors with the Air Molecules. Owing to the high velocity of meteors (30—70 km/sec.), the temperature motion of the air molecules can be neglected when we treat the penetration of a meteor into the atmosphere. The researches of Knudsen, Wood, Taylor and others (1) have shown the reflection of the molecular beams from the surfaces of solid bodies to be of a diffusive character. In such a case the average length of the segment, over which the reflected molecule passes within the limits of the cylinder described by the meteor, is of the same order as its diameter. According to modern points of view as to the structure of the atmosphere, the average length of a free path of a molecule is of the order of 1 cm at the height of 100 km, and of kilometers at the height of 200 km. Consequently, all the air molecules at such heights reach the surface of a meteor with a relative velocity, equal to that of the meteor. The kinetic energy of their relative motion is of the order of some hundreds of electron-volts. This energy is many times as great as that of dissociation or ionization, and therefore even if these processes were to take place (which is scarcely probable), the collision of an air molecule with a meteor may be regarded as an absolutely elastic collision with one or several molecules (consecutively) of the meteor. The kinetic energy gained by a meteor molecule (characterized by the accomodation coefficient a) is a heat energy with respect to the whole meteor, and thus the collision of an air molecule is not absolutely elastic as regards the whole meteor. The calculation of the mean accomodation coefficient may be carried out according to the formulae that had been checked experimentally at the study of a gas discharge (2, 3). The composition of the atmosphere being nitro-oxygenous, we get for an iron meteor $a=0.75$, for a stony meteor $\bar{a}=1$.

Heating of the Meteor. Let us assume that the variation of the atmosphere density with height on separate portions which are of interest to us, may be represented by the exponential law:

$$\rho=\rho_0 e^{-\frac{H}{H^*}} \ldots \qquad (1)$$

The velocity of the meteor decreased markedly at the very end of its path, and therefore, for the upper part of it we may esteem that

$$H=-v_0 \cos zt, \qquad t<0 \qquad (2)$$

(z—the zenith distance of the radiant).

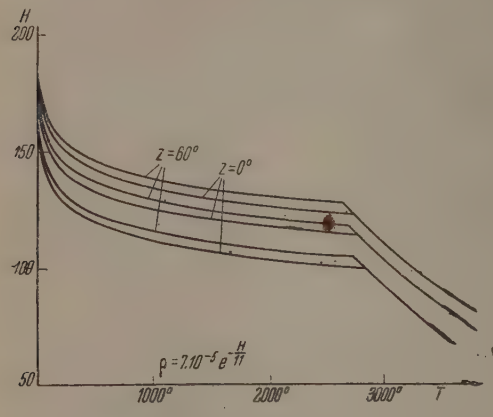
The contrary shocks of air molecules heat the meteor's front surface. The flux of energy passing over the area 1 cm² of the front surface—the normal to which forms the angle α with the direction of the motion—is equal to

$$W = \bar{a}\,\frac{\rho v_0^3}{2}\cos\alpha = \bar{a}\,\frac{\rho_0 v_0^3}{2}\cos\alpha\, e^{-\frac{v_0\cos z}{H^*}t}. \qquad (3)$$

Let us examine the heating of the non-rotating cylindrical meteor with a flat front surface (the axis of the cylinder coincides with the direction of the motion). The meteor being of a size sufficiently large, its rear surface remains practically cold; consequently, we may use the solution of the equation of heat conduction for the rod limited from one side, with the given flux through the boundary*. It gives

$$T(x, H) = \frac{\bar{a} b \sqrt{H^*}}{2\lambda}\,\frac{v_0^{5/2}}{\sqrt{\cos z}}\,\rho(H)\, e^{-\frac{1}{b}\sqrt{\frac{\rho_0\cos z}{H^*}}x} \qquad (4)$$

(x—distance from the front surface of the meteor, $b^2 = \frac{\lambda}{Dc}$, D—density of the meteor, c—specific heat, λ—the coefficient of heat conduction). T increases proportionally to ρ, hence, the heating of the meteor takes place very rapidly within the limits of a very thin layer of atmosphere. When characterizing the depth of the heating by the thickness of surface layer x_0, within which limits T decreases e-fold, we obtain that x_0 does not depend on t.



$$x_0 = b\sqrt{\frac{H^*}{\rho_0\cos z}}. \qquad (5)$$

The substitution of numerical values in (5) shows the depth of the heating to be very small—about 1.5 mm for the iron meteor and less than 0.5 mm for the stony meteor. It follows that (4) may be applied to meteors of a very small dimension.

The temperature of the meteor, at a certain height, reaches the value, at which the vapour pressure of the meteor substance is equal to the front pressure on the meteor. Violent evaporation (boiling) sets in which slows down the rise of the temperature. Its further rise is due to the increase of the front pressure, as the meteor penetrates into denser layers of the atmosphere (Fig. 1). The beginning of a violent evaporation seems to determine the point of appearance of the meteor.

Owing to the fact that great alterations in pressure change but little the temperature of boiling, the temperature at the moment of the appearance of meteors of different velocity and different inclination is practically the same (for iron meteors—2700—2800°K). Therefore (4) makes it possible to find the density at the height of the appearance of meteors. At the same time

* The radiated flux of energy all over the path of the meteor is much smaller than the one obtained from the shocks of air molecules.

the dependence of the height of appearance H_1 on the velocity and inclination allow to find H^*, determining the composition and temperature of the atmosphere $\left(H^* = \frac{RT}{\mu g}\right)$. None of the constants of the meteor itself enter the expression for these dependences:

$$\frac{\partial H_1}{\partial v_0} = \frac{5}{2}\frac{H^*}{v_0} \qquad (6\,a)$$

$$\frac{\partial H_1}{\partial z} = \frac{H^*}{2}\operatorname{tg} z. \qquad (6\,b)$$

Observational data relating to these dependences are in favour of $H^* \approx$ ≈ 10 km (nitro-oxygenous atmosphere) and fully contradict the hypothesis of the prevailing of light gases at the height of 100—140 km.

Evaporation and Deceleration of the Meteors.- Practically all the energy gained by a meteor (lower than the point of appearance) serves for the evaporation of the surface layer and for the heating of the underlying one up to the boiling temperature. Therefore the loss of the mass of a meteor is given by the equation:

$$dM = \frac{\bar{a}\mu_m}{2(L+\bar{Q})\cos z} S v^2 \rho\, dH \qquad (7)$$

(S—area of the front section, μ_m—molecular weight of the meteor, L—latent heat of evaporation pro grammol, $\bar{Q}$—average heat necessary for the heating of 1 grammol up to boiling temperature).

The deceleration of a meteor is determined by the law of the preservation of impulse. Disregarding the velocity of the evaporating molecules with respect to the meteor, as compared with the velocity of the meteor itself, we obtain:

$$Mdv = -(1+k)\, vdm = \frac{1+k}{\cos z} S v \rho\, dH \qquad (8)$$

dm—mass of the collided air molecules, k—a factor characterizing the reaction of the air molecules diffusely reflected from the meteor with the velocity

$$k = \frac{2}{3}\frac{\sqrt{1-\bar{a}}}{S}\int \cos^2\alpha\, d\sigma \qquad (9)$$

(the integral over all the front surface). For a flat front surface $k = \frac{2}{3}\sqrt{1-\bar{a}}$ and (8) gives the pressure on the flat front surface

$$P = \left(1 + \frac{2}{3}\sqrt{1-\bar{a}}\right) v^2 \rho. \qquad (10)$$

Dividing (7) by (8) and integrating we obtain

$$M = M_0\, e^{-A(v_0^2 - v^2)}; \qquad A = \frac{\bar{a}\mu_m}{4(L+\bar{Q})(1+k)}. \qquad (11)$$

If $v \to 0$, the mass tends to a certain limit which is comparatively large for slow meteors (for an iron meteor with $v_0 = 30$ km/sec. $\lim M = 2 \cdot 10^{-6} M_0$). The greater part of the meteor evaporates on that section of its path, when the velocity decreases but by 1—2 km. From the initial kinetic energy of the meteor $\frac{M_0 v_0^2}{2}$ a considerable part $\left(1 - \frac{1}{Av_0^2}\right)\frac{M_0 v_0^2}{2}$ is taken away by evaporating molecules. Only a small part ($^1/_{13}$ for an iron meteor if $v_0 = 30$ km/sec. and $^1/_{71}$ if $v_0 = 70$ km/sec.) serves for the evaporation of the meteor and for

communicating kinetic energy to the air molecules immediately colliding with the meteor. Out of the latter part, the quantity of energy serving for the evaporation is equal to

$$\eta = \frac{\bar{a}}{2(1+k)} \cdot \tag{12}$$

By substituting (11) to (8) we get the dependence of the velocity on the height for the non-revolving cylindrical meteor:

$$e^{-Av_0^2}[Ei(Av_0^2) - Ei(Av^2)] = \frac{2(1+k)}{\cos z} \frac{S}{M_0} H^* \rho(H) \tag{13}$$

where $Ei(x)$ is the integral exponential function. An analogous formula is derived for a revolving spherical meteor. The impediment is of an extremely rough character, as practically but a very small fragment of the meteor is being impeded [see (11)]. The height of the disappearing point H_2 is derived from (13), assuming that $Ei(Av^2) \approx 0$. The dependence of H_2 on the initial velocity, on the inclination, as well as on the initial size and density is such:

$$\frac{\partial H_2}{\partial v_0} = 2\frac{H^*}{v_0} \tag{14a}*$$

$$\frac{\partial H_2}{\partial z} = H^* \operatorname{tg} z \tag{14b}$$

$$\frac{\partial H_2}{\partial (RD)} = \frac{H^*}{RD} \cdot \tag{14c}$$

From (13) it follows that the mass of iron meteors disappearing at the height of about 80 km («ordinary» meteors) must be of the order 10^{-2} g.

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* Approximate formula for the great initial velocities. The formula is somewhat more complex for small velocities.

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MATHEMATISCHE PHYSIK

ZUR BEUGUNG AN EINEM SPALT, RESP. STREIFEN. I

Von W. S. IGNATOVSKIJ (W. IGNATOWSKY), korrespondierendem Mitglied der Akademie

Wir gehen wieder aus von der Wellengleichung

$$\frac{\partial^2 u(x,y)}{\partial x^2}+\frac{\partial^2 u(x,y)}{\partial y^2}+\varkappa^2 u(x,y)=0 \qquad (1)$$

wobei wir einen Spalt, resp. Streifen, von der Breite $2a$, parallel der Z-Achse, betrachten.

Das Koordinatensystem ist wie bei dem Gitter (1) gelegen, und der Koordinatenanfang halbiert den Spalt, resp. den Streifen. Es sind demnach die Gleichungen

$$u(x,y)=\frac{1}{\pi}\int_0^\infty H_0(y-s)\,Q_0(\varkappa\sqrt{x^2+s^2})\,ds+$$

$$+\frac{1}{\pi}\int_0^\infty H_0(y+s)\,Q_0(\varkappa\sqrt{x^2+s^2})\,ds \qquad (2)$$

falls $H_0(y)=\left.\frac{\partial u(x,y)}{\partial x}\right|_{x=0}$ längs der YZ-Ebene gegeben ist [siehe (10) in (1)] und

$$u(x,y)=\frac{i}{\pi}\frac{\partial}{\partial x}\int_0^\infty N_0(y-s)\,Q_0(\varkappa\sqrt{x^2+s^2})\,ds+$$

$$+\frac{1}{\pi}\frac{\partial}{\partial x}\int_0^\infty N_0(y+s)\,Q_0(\varkappa\sqrt{x^2+s^2})\,ds \qquad (3)$$

falls $N_0(y)=u(0,y)$ auf der YZ-Ebene gegeben wird [diese Gleichung folgt aus (6) (1)], gültig.

Immer ist die elektrische Kraft der einfallenden Welle, welche sich parallel der positiven Richtung der X-Achse bewegt, gleich $e^{-i\varkappa x}$.

Im Falle I ist die elektrische Kraft parallel der Z-Achse und demnach ergibt sich $H_0(y)=-i\varkappa$ für die einfallende Welle (9) (1).

Im Falle II ist die magnetische Kraft der Z-Achse parallel und diejenige der einfallenden Welle auf der ZY-Ebene ist $\frac{1}{c}$.

Es wird immer für unsere Lösung sein

$$H_0(y) = H_0(-y);\ N_0(y) = N_0(-y). \tag{4}$$

Die Gleichung (1) wird, augenscheinlich, von der rechten Seite von (3) erfüllt werden, auch ohne der Differentiation nach x. Setzen wir deshalb die so erhaltene Gleichung in (1) ein, machen dann $x=0$, so erhalten wir, unter Berücksichtigung der Bedeutung von $H_0(y)$,

$$-H_0(y) = \varkappa^2 C(y) + \frac{d^2C(y)}{dy^2} \tag{5}$$

wobei

$$C(y) = \frac{1}{\pi}\int_0^\infty N_0(y-s)\,Q_0(\varkappa s)\,ds + \frac{1}{\pi}\int_0^\infty N_0(y+s)\,Q_0(\varkappa s)\,ds \tag{6}$$

sein wird.

Wir gehen jetzt zum Spalt über und speziell zum Fall I.

Hierbei setzen wir $u(x, y)$ gleich der elektrischen Kraft, welche überall stetig sein wird und auf dem Schirm, ausserhalb des Spaltes, verschwindet.

Aus (2) folgt dann für $x=0$:

$$u(0, y) = N_0(y) = \frac{1}{\pi}\int_0^\infty H_0(y-s)\,Q_0(\varkappa s)\,ds + \\ + \frac{1}{\pi}\int_0^\infty H_0(y+s)\,Q_0(\varkappa s)\,ds \tag{7}$$

oder auf Grund des Gesagten und unserem Satze (1), statt (7)

$$N_0(y) = -\frac{i\varkappa}{\pi}\int_0^{a+y} Q_0(\varkappa s)\,ds - \frac{i\varkappa}{\pi}\int_0^{a-y} Q_0(\varkappa s)\,ds + \\ + \frac{1}{\pi}\int_a^\infty H_0(s)\,Q_0[\varkappa(s+y)]\,ds + \frac{1}{\pi}\int_a^\infty H_0(s)\,Q_0[\varkappa(s-y)]\,ds; \quad |y| \leqq a. \tag{8}$$

Aus (6) ergibt sich für den jetzigen Fall

$$C(y) = \frac{1}{\pi}\int_{-a}^{+a} N_0(s)\,Q_0[\varkappa(s+y)]\,ds; \quad y \geqq a. \tag{9}$$

Die Gleichung (5) folgt aus (3) und (8) aus (2). Beide zusammen ergeben nun eine Integralgleichung zur Bestimmung von $N_0(y)$. Wir erhalten deshalb, unter Berücksichtigung der Differentialgleichung für $Q_0(x)$, als gesuchte Integralgleichung

$$N_0(y) = -\frac{i\varkappa}{\pi}\int_0^{a+y} Q_0(\varkappa s)\,ds - \frac{i\varkappa}{\pi}\int_0^{a-y} Q_0(\varkappa s)\,ds + \\ + \int_{-a}^{+a} N_0(t)\,K(y, t)\,dt; \quad |y| \leqq a \tag{10}$$

mit

$$K(y, t) = -\frac{\varkappa^2}{\pi^2}\int_a^\infty \frac{Q_1[\varkappa(t+s)]}{\varkappa(t+s)}\left\{Q_0[\varkappa(s+y)] + Q_0[\varkappa(s-y)]\right\}\zeta ds. \tag{11}$$

Die hier vorkommende Vertauschung der Integrationsfolge lässt sich rechtfertigen.

Nun gehen wir zu dem Streifen, und zwar zum Fall II, über. Hierbei verstehen wir jetzt unter $u(x, y)$ die magnetische Kraft und führen nun die Grösse

$$Z_0(y) = 1 - cN_0(y) \tag{12}$$

ein, wobei also $N_0(y)$ in diesem Fall die magnetische Kraft auf der ZY-Ebene darstellt.

Laut dem oben Gesagtem ist $Z_0(y)$ überall stetig und, laut unserem Satze, Null auf der YZ-Ebene, ausserhalb des Streifens. Wir setzen deshalb in (9) $Z_0(y)$ statt des dortigen $N_0(y)$ und erhalten eine Grösse, welche wir durch $C_1(y)$ bezeichnen.

Beachten wir ausserdem die bekannte Beziehung

$$\int_0^\infty Q_0(\varkappa s)\, ds = \frac{i\pi}{2\varkappa} \tag{13}$$

so ergibt uns (6)

$$C(y) = \frac{i}{\varkappa c} - \frac{1}{c} C_1(y). \tag{14}$$

Aus (5), wobei jetzt $H_0(y)$ proportional der Y-Komponente der elektrischen Kraft in der YZ-Ebene sein wird, folgt nun

$$cH_0(y) = i\varkappa - \varkappa^2 C_1(y) - \frac{d^2 C_1(y)}{dy^2}. \tag{15}$$

Da wir den Wert von $N_0(y)$ nur innerhalb des Streifens brauchen, denn ausserhalb ist uns $N_0(y)$, d. h. die magnetische Kraft, bekannt und zwar, laut unserem Satze, gleich $\frac{1}{c}$, so ergibt uns (2) in diesem Fall, wobei wir, laut (12), sofort zu $Z_0(y)$ übergehen

$$Z_0(y) = 1 - \frac{c}{\pi} \int_0^\infty H_0(s) \{Q_0[\varkappa(s+y)] + Q_0[\varkappa(s-y)]\}\, ds. \tag{16}$$

Hierein (15) eingesetzt und wieder unter Beachtung von (13), bei einer Vertauschung der Integrationsfolge, wie in (10), erhalten wir aus (16)

$$Z_0(y) = -\frac{i\varkappa}{\pi} \int_0^{a+y} Q_0(\varkappa s)\, ds - \frac{i\varkappa}{\pi} \int_0^{a-y} Q_0(\varkappa s)\, ds +$$

$$+ \int_{-a}^{+a} Z_0(t)\, K(y, t)\, dt; \qquad |y| \leqq a \tag{17}$$

mit derselben Bedeutung von $K(y, t)$, wie in (11).

Wir ersehen nun, dass (17) identisch mit (10) sein wird, nur dass hier $Z_0(y)$ an Stelle des dortigen $N_0(y)$ steht.

Deshalb erhalten wir, wie für den Spalt im Falle I, so auch für den Streifen im Falle II, ein und dieselbe Integralgleichung (10), resp. (17).

Diese Gleichung können wir umformen und machen zu dem Zwecke $y = a$. Dann folgt aus (17)

$$0 = -\frac{i\varkappa}{\pi} \int_0^{2a} Q_0(\varkappa s)\, ds + \int_{-a}^{+a} Z_0(t)\, K(a, t)\, dt. \tag{18}$$

Subtrahieren wir dies von (17), so ergibt sich

$$Z_0(y) = \frac{i\varkappa}{\pi} \int_y^a \{Q_0[\varkappa(a+s)] - Q_0[\varkappa(a-s)]\}\, ds + \\ + \int_{-a}^{+a} Z_0(t)\, K_1(y, t)\, dt; \quad |y| \leqq a \tag{19}$$

wobei

$$K_1(y, t) = K(y, t) - K(a, t) \tag{20}$$

bedeutet.

Wir können dies weiter umformen, wenn wir setzen

$$N_0(y) = \int_y^a F(\eta)\, d\eta \quad |y| \leqq a \tag{21}$$

mit

$$F(\eta) = -F(-\eta) \tag{22}$$

und erhalten aus (19)

$$F(y) = \frac{i\varkappa}{\pi} \{Q_0[\varkappa(a+y)] - Q_0[\varkappa(a-y)]\} + \\ + \int_{-a}^{+a} F(\eta)\, K_2(y, \eta)\, d\eta; \quad |y| < a \tag{23}$$

mit

$$K_2(y, \eta) = -\frac{\varkappa^2}{\pi^2} \int_{-\eta}^{+\eta} dt \int_a^{\infty} \frac{Q_1[\varkappa(t+s)]}{t+s} \{Q_1[\varkappa(s+y)] - \\ - Q_1[\varkappa(s-y)]\}\, ds; \quad |y| < a. \tag{24}$$

Die entsprechenden Kerne, wie man ohne weiteres sieht, sind nicht symmetrisch in Bezug ihrer Argumente. Sie sind aber stetig, wie wir dies weiter ersehen werden.

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PHYSICS

INFLUENCE OF CHEMICAL BOND UPON THE $K\beta$ GROUP OF THE X-RAY SPECTRUM OF CHROMIUM

By M. A. BLOKHIN

(Communicated by S. I. Wawilow, Member of the Academy, 22. IX. 1939)

The chromium group was studied by quite a number of investigators ([1-7]). However, the data obtained are far from being exhaustive and are even to a certain extent at variance with one another. Recent developments in spectroscopic technique make it desirable to examine this group anew and this time with the help of a strong-light spectrograph provided with a curved crystal, according to Johann's method. For this purpose the vacuum spectrograph of H. Karlsson and M. Siegbahn ([8]) was made use of with a quartz crystal cut out along the plane of the prism. The radius of curvature of the crystal was 500 mm. Owing to the broad focal spot of the anode of the X-ray tube, the load, with a voltage of 20 kV, did not exceed 3.6 W, which prevented the excessive heating of the specimen and consequently obviated chemical reactions on the anode. Among the substances under investigation such as: metallic chromium, Cr_2O_3, $Cr_2(SO_4)_3$, K_2CrO_4, $SrCrO_4$, $BaCrO_4$, $PbCrO_4$ and natural chromespinel, only $PbCrO_4$ underwent decomposition on the anode. Notwithstanding the facility with which metallic chromium ([4]) undergoes oxidation, it was found possible to obtain its spectrum which was widely different from that of Cr_2O_3. On the other hand, investigations by the method of fluorescence ([2,3]) gave so weak a spectrum, that they yielded but very limited results. According to Druyvesteyn ([9]), the relative intensity of satellites with reference to diagram lines, when using the fluorescence method, was two or three times less than with primary excitation. This is why in the present work we had recourse to the method of primary excitation. The results of measurement of wave length are summarized in Table 1.

Line $K\beta_1$ responds but little to the influence of chemical bonds. Line $K\beta_5$ upon passage from metal to oxide was found to become displaced by 1 *XE* in the direction of the long-wave-length side and to decline in intensity one and half times, while it became at the same time considerably more symmetrical. The initial level of transition $K\beta_5$ is $M_{IV, V}$. The electrons of this level are with chromium valent electrons. The breadth and the shape of level $M_{IV, V}$ in the metallic condition give the breadth and the shape of the energy level of conductivity electrons. In conformity with this, β_5 with the metal has a sharply marked short-wave-length boundary and a gradual fall of intensity on the long-wave-length side. With hexavalent chromium on the level $M_{IV, V}$ and in non-excited state electrons are absent, wherefore in such compounds β_5 is a semi-optical line, which fact should necessarily

Table 1

Measurements of Wave-Lengths λ in XE $K\beta$ for the Chromium Group

Line \ Ion	Metallic chromium	Cr_2O_3	$Cr_2(SO_4)_3$	Chrome-spinel	K_2CrO_4	$SrCrO_4$	$BaCrO_4$	$PbCrO_4$
β''''	2057.25	2057.55	2057.58	2057.54	—	—	2057.92	2057.41
β_a'''	2060.97	2060.93	2060.99	2060.99	2061.03	2061.31	2061.16	2061.12
β_b'''	—	2063.26	2063.09	2063.32	—	—	—	2063.34
β_5^*se	2065.83	2066.50	2066.40	2066.66	2065.80	2066.07	2065.79	2066.33
β_5^a	2066.74	—	—	—	2066.42	—	2066.59	—
β_5	—	2067.83	2067.62	2067.60	2067.67	2067.55	2067.73	2067.70
β''	—	2073.57	2073.48	2073.46	2071.97	2072.20	—	2073.46
β_1	2080.58	2080.27	2080.28	2080.30	2080.52	2080.57	2080.40	2080.39
β'	2086.08	2085.70	2085.58	2085.60	2085.68	2085.54	2085.74	2085.77
η	2111.35	—	—	2112.0	—	—	—	2111.80

involve a sharp decrease in its intensity. The optical levels of an atom represent, owing to disturbances on the part of neighbouring atoms, zones of considerable breadth. Therefore with hexavalent chromium, breadth β_5 ought to grow. All these proportions are indeed distinctly observable. Besides this, with K_2CrO_4 and $BaCrO_4$, β_5 is a duplicate.

Tervalent compounds are at level $M_{IV, V}$ short of two electrons, which reduces the screening of this level, bringing it to the respective level 26 Fe. With iron, the energy of $M_{IV, V}$ level is by 0.3 ridberg higher than with chromium. This should with tervalent chromium produce a corresponding displacement β_5 amounting to 0.3 ridberg and running towards the long-wave-length region, as compared with metallic chromium. This relationship is maintained not only qualitatively, but in order of size, too (1 XE, which corresponds to 0.2 ridberg), and also quantitatively.

$K\eta$ is an extremely faint, broad diffuse line. Beuthe ([10]) explains it by the prohibited transition $K—M_I$, however, calculation gives a too high value of $\frac{\nu}{R}$. Such divergence may be explained by the following mechanism: transition $K—M_I$ barred by the rules of selection, is attended by the emission of 1 quantum of radiant energy and 1 electron from level $M_{II, III}$. In Table 2 is to be found a confrontation of the difference of energies between transition $(K—M_I)_z$ and line η with term $\frac{\nu}{R}$ of level $(M_{II, III})_{z+1}$ of the next element.

This computation gives the short-wave-length boundary of the line, since the electron ejected from the atom can receive a certain kinetic energy, while the measured values of $\frac{\nu}{R}$ for $K\eta$ refer to the maximum of intensity. For this reason the values of $\frac{\nu}{R}$ for $(M_{II, III})_{z+1}$ of the next element ought

* Se—short-wave-length edge.

to be somewhat less than quantity $[(K-M_{\mathrm{I}})_z-\eta]$. We observe a fair agreement for elements within the range of 23 V to 28 Ni. For heavier elements the mechanism of the appearance of $K\eta$ becomes, as it seems, more complicated, which is possibly connected with the filling in of level $M_{\mathrm{IV,\,V}}$ with 29 Cu.

It will be possible to explain in a similar way the appearance of satellite $K\beta'$, provided we admit that upon transition $K-M_{\mathrm{II,\,III}}$, there will take place the simultaneous emission of a quantum of radiant energy and of one electron from level $M_{\mathrm{IV,\,V}}$. In fact, the difference of terms $\frac{\nu}{R}$ between the short-wave-length edge of $K\beta'$ and the maximum of intensity $K\beta_1$ is equal to 0.51 ridberg (for metallic chromium), while the energy of the level $(M_{\mathrm{IV,\,V}})_{z-1}$ (i. e. with manganese) is equal to 0.43 ridberg. This mechanism, associated with the emission of the electron from the atom, should

Table 2

Interpretation of $K\eta$

Element	$K-M_{\mathrm{I}}-\eta$	$(M_{\mathrm{II,\,III}})_{z+1}$
23 V	3.6	3.1
24 Cr	3.8	3.8
26 Fe	5.0	4.7
27 Co	5.4	5.7
28 Ni	6.1	5.7
29 Cu	5.2	6.7
30 Zn	5.3	9.5
31 Ga	6.1	8.8
32 Ge	0.9	10.3

Fig. 1. Plot of curves β' and β_1 for $BaCrO_4$.

give the shape of the curve of intensity β' with a steep fall in the direction of short-wave-lengths and with a gentle slope in the direction of long-wave-lengths, which is indeed observable (e. g., see the plot of curves β' and β_1 for $BaCrO_4$, Fig. 1). Finally, the same mechanism explains in a satisfactory manner the increase of the gap between β' and β_1, available upon transition from metal to oxide. Indeed, with an oxide, the energy of level $M_{\mathrm{IV,\,V}}$ actually increases to 0.2 ridberg, which involves an increase of the distance between the short-wave-length edge of β' and maximum intensity β_1.

Satellite β'' is absent with metallic chromium. With tervalent compounds it is distinctly observable, while with hexavalent compounds its brightness appreciably increases still more, and it becomes displaced in the direction of short-wave-lengths by nearly 1.5 *XE*. Such a strong dependence upon chemical bonds is unquestionably indicative of the fact that the origin of this satellite is connected with the peripheral levels of a chromium atom. However, semi-Mosley diagrams give an extremely great scattering of points, both in the case when β_1 is selected as the generating line and in the case when β_5 is selected. The mechanism of the generation of this line cannot be well accounted for by any of the existing theories. β''' of metal is a solitary line, but with tervalent and hexavalent compounds it forms a double (with hexavalent compounds only the long-wave-length component has been measured). β'''' was until the present time known only up to 21 Sc, while with chromium it was detected for the first time. With increase of valency, β''' and β'''' become displaced in the direction of long-wave-lengths. With metals, this shape is sharply asymmetrical, having a steep fall of intensity of the short-wave-length edge and a gentle slope of the long-wave-length edge.

With compounds, however, these lines are symmetrical. For the interpretation of satellites $\beta'''_{a,\,b}$ and β'''' calculations were performed, on the one hand, of values of $\frac{\Delta\nu}{R}$ for satellites with reference to $K\beta_1$ and, on the other hand, of values $\frac{\Delta\nu}{R}$ for all possible cases of double and triple ionization. β'''_a of chromium fails to be explained either by double or triple ionization and, possibly, arises as a result of KL-ionization with a subsequent transition of electron $M_{\mathrm{II,\,III}}$ to level K, with simultaneous emission for the atom of one $M_{\mathrm{IV,\,V}}$ electron.

Satellite β'''' is accounted for by triple KLM_{I}-ionization which at the same time forms the reason for its extreme weakness. Comparisons of results for β'''_a and β'''' are recorded in Table 3.

Table 3

Calculated and Measured Values of $\Delta\nu/R$ for β'''_a and β''''

Line	Meas. $\Delta\nu/R$	Transition	Calc. $\Delta\nu/R$
β'''_a	4.1—4.2	$KL—LM_{\mathrm{II,\,III}}M_{\mathrm{IV,\,V}}$	4.0—4.2
β''''	4.8—4.9	$KLM—LM_{\mathrm{I}}M_{\mathrm{II,\,III}}$	4.7—4.9

The observed characteristics of the spectra of chromium in the metallic state, as well as in tervalent and hexavalent compounds, permit to establish the valency of chromium in minerals and compounds. The data obtained by previous investigators show that in a number of cases, due to heating at the anode, instead of metallic chromium its oxide had really been investigated.

In closing, the author deems it a pleasant duty to express his aknowledgement to Prof. M. Siegbahn, to whom he owes the theme of the present work.

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CHEMISTRY

CERTAIN PROBLEMS OF THE THEORY OF PHYSICAL-CHEMICAL ANALYSIS

By N. S. KURNAKOV, Member of the Academy, and M. A. KLOCHKO

1. The problem of a change in the properties of chemical systems in equilibrium depending on changes in composition has since long attracted the attention of investigators. Yet, all attempts to express these dependences in terms of equations derived from thermodynamic principles or from molecular-kinetic conceptions involved the use of highly cumbersome formulae which, besides, were but very seldom found to be justifiable when real systems were concerned. For this reason it was found advisable to express the dependence of property (ε) on composition (*x*) either by means of empirical formulae or in the form of geometrical figures—lines or surfaces. But, in respect of the interpretation of curves composition—property (*x*-ε curves) there still exist some contradictions, pointed out among others by G. Senter (1) and H. Dawson (2) in their reviews published in the «Annual Reports on the Progress of Chemistry of the British Chemical Society».

In a monograph devoted to the properties of binary liquid systems, R. Kremann (3) has discussed a number of properties, each of which is, however, considered outside of any connexion with the other ones. It is, indeed, only in chapter I of this paper that several general problems are touched upon, namely: change in appearance of *x*-ε curves upon transition from gravimetric to molecular percentage, or from a certain normal property to the reverse one.

2. A special domain of General Chemistry known as physical-chemical analysis and being investigated by N. S. Kurnakov and co-workers, is devoted to the solution of the problem of the connexion existing between the composition and the properties of chemical systems in equilibrium. More generally speaking, the problem may be formulated as a study of the dependence of the properties of chemical systems upon their equilibrium conditions (the concentration of the components building up the system falling also under this head). The application of the geometrical method for the study of the chemical nature of systems (4) is to be regarded as the essential feature of present-day physical-chemical analysis.

Two general principles are applicable to the whole range of *x*-ε curves (and figures) which are termed chemical diagrams.

1. Continuity Principle. With a continuous change in the composition of a system (or other factors of equilibrium), its properties are also liable to change continuously; the *x*-ε curves illustrating relations will likewise be continuous.

2. Correlation Principle. A definite geometrical figure in the diagram ([5]) will be found to correspond to every individual chemical compound or phase of variable composition in the system.

The results of the qualitative investigation of the common or «topological» properties of a diagram are discussed by N. S. Kurnakov in a number of works ([5]). Investigations into the methods of representing polycomponent systems are being conducted by V. J. Anossov ([6]) and V. P. Radishtchév ([7]); a study of the «metric», i. e. the quantitative relationships for the elements of a chemical diagram based on the law of mass action, was carried out by the late N. I. Stepanov ([8]).

3. However, doubts may arise as to the expediency of considering the whole problem composition—property from a single general viewpoint, while, at the same time, the existence of common feature in the x-ε diagram may also be questioned: 1) for diverse classes of chemical individual compounds; 2) for systems with a different number of components and equilibrium conditions; 3) for various properties.

However, a close study of the accumulated material does indeed lead to a recognition of common features available with different diagrams.

1. The types of diagrams of a given property depend not only on the chemical functions of the available components, but also on the processes taking place in the systems and involving a change in the number of molecules of different kind, or the formation of new chemical compounds or phases of variable composition, the disintegration of polymers, etc. It is well known that the types of equilibrium diagrams developed by Rooseboom are represented both by metal systems and by systems for salts, organic and mixed compounds. The same fact is available also for other properties, such, for instance, as viscosity: the «singular» type of the viscosity diagram discovered by N. S. Kurnakov and S. F. Zhemchuzhny in course of studying systems of mustard-oils and amines ([9]) is found to be fully applicable also to the potassium-sodium system, whose viscosity was investigated by R. Kremann and co-workers ([10]); there is here the same «singular» maximum corresponding to the composition of the chemical compound formed in the liquid phase.

2. Each diagram for a polycomponent system may be envisaged as one formed out of a diagram for a system with a lesser number of components, but made more complex by the introduction of new components or new equilibrium conditions, the characteristic elements of the simpler system failing, however, to disappear therethrough, but only assuming another geometrical form. Thus, for instance, a «singular» point in a binary system is transformed into a «singular» fold in a ternary system ([11]); the isotherm of a ternary system repeats on the whole the polytherm of a binary system, etc.

3. Finally, the cases of comparison of x-ε diagrams for different properties cited in the literature can have significance only provided the investigators applying this method are convinced, that a diagram of different properties holds such general features which point to a change in the number of chemical compounds, the existence of phases of variable composition, etc., all this being independent of the property under consideration. As an instance, we might point to the similarity of the types of fusibility diagrams in the case of solid solutions with the diagrams composition—vapour density, or else, to the interconnexion between the curves «temperature coefficient—composition» for viscosity and electric conductivity ([12]).

4. The availability of common features in diagrams of different properties which may be characterized as the intrinsic unity of structure of chemical diagrams, is associated with the fact, that the latter univocally represent the processes that take place in connexion with the interaction of the compo-

nents of a system and which exert their influence upon the quantitative expression of the properties of that system. If the components of the system form no new chemical compounds, and no change in the magnitude of molecular aggregates (depolymerization, association, etc.) takes place in the system, then the magnitude of the property changes more or less uniformly with composition, following in most cases the course of curves approaching a straight line or a hyperbole in their form.

Now, if interaction between components involves the formation of a new chemical compound which, in the general case, shows for a number of properties such numerical values as are different from the respective values of the initial components or from the calculated ones for their mixtures, then, a special point will appear on the x-ε diagram, corresponding to the composition of the given chemical compound and failing to change its abscissa upon changing the equilibrium conditions of the system within the region of the stable existence of the given compound. In the case of binary mixtures and a compound which would not be dissociated into its initial components, a «singular» point appears on the diagram.

5. The fact of the appearance of a new chemical compound formed by the components of a given system may be also expressed analytically, by means of equations representing the change in the magnitude of the given property of this compound as depending upon the addition of one or the other of the initial components of the system. But a study of the quantitative expressions for various properties of chemical compounds, as dependent upon their atomic composition and molecular structure, constitutes a problem which is up to the present far from being solved, this fact being plainly borne out, for instance, by the latest monograph of R. Kremann devoted to the question ([13]); as regards the analytical expressions of the properties of a system as a function of composition, here, as already mentioned in § 1, considerable difficulties are found to lie in the path of finding a correct solution to the problem.

These difficulties prompt to select a geometrical way for a representation of the dependence of properties on composition, as well as on the other conditions of equilibrium of the system. The application of geometrical concepts in chemistry holds indeed extensive theoretical possibilities. Van-der-Waals and Konstamm ([14]) maintain that in those cases when analysis, i. e. the expression of physical properties with the help of quantitatively definite functions, fails to be applicable, we should, for further advancement of our investigation, have recourse to geometrical representations. The immense importance of the geometrical method in the development of physical-chemical knowledge is brought forward by F. G. Donnan in his work devoted to the influence of Gibbs' research upon physical chemistry ([15]). Finally, G. Tammann states directly that without the application of a geometrical method the study of hetergeneous systems would be outside the limits of possibility ([16]).

Physical-chemical analysis, called upon to investigate the changes in the properties of a system depending upon variation in equilibrium conditions (concentrations of components being also considered as an equilibrium condition), and dealing with complex functions of many variables, makes use of the geometrical method as a most important tool for its investigations. This method is, in particular, of service in representing the composition of many-component systems. The up-to-day importance of the problem is urged in a number of works, the latest among them being an article by Randdall and Longtin ([17]).

6. In order to establish the general mechanisms, inherent in chemical diagrams, physical-chemical analysis resorts to data borrowed from that, most

general part of geometry which bears the name of topology or qualitative geometry.

It is not for the first time that topology has been applied in physical-chemical sciences. Faraday had no recourse to mathematical analysis in his works, however, he employed, as certified by J. C. Maxwell, a special mathematical method which he applied, in particular, to working out his conception of lines of force [18]. This method is a geometrical one, as Faraday was, in the opinion of J. J. Thomson, «a born geometer» [19]; in fact in his work he applied the ideas of the most general part of geometry—topology, which in those days had not yet been elaborated by mathematical scholars.

Maxwell, who, as evidenced by his contemporaries, preferred the geometrical method to the analytical one [19], made use of topology in his «Treatise on Electricity and Magnetism» [18], emphasizing in the introduction to his work the significance of the «geometry of position» (topology). In another paper of his he especially treats topological problems [20].

Particularly noteworthy is the application of topology to thermodynamics, i. e. to that branch of physical-chemical sciences which almost solely made use of analysis. Van-der-Waals proposes to make use of the methods of qualitative geometry even in the study of the simplest systems—the binary ones [14], volume II).

The application of the methods of qualitative geometry to the study of chemical systems of equilibrium represents at the present stage of development of physical-chemical analysis a task of the highest importance; the solution of this problem will necessarily lead to fruitful results both in the field of theory and in the numerous practical applications of this new part of general chemistry.

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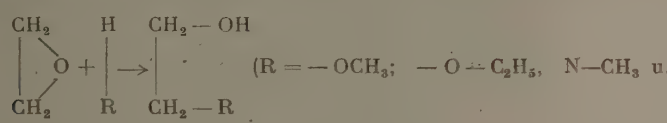
CHEMIE

ÜBER EINE NEUE REAKTION MIT ÄTHYLENOXYD. KONDENSATION DES ÄTHYLENOXYDS MIT MALONESTER

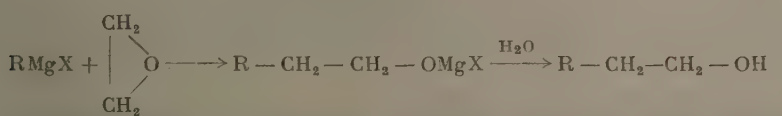
Von K. G. PACKENDORFF

(Vorgelegt von N. D. Zelinsky, Mitglied der Akademie, d. 12. IX. 1939)

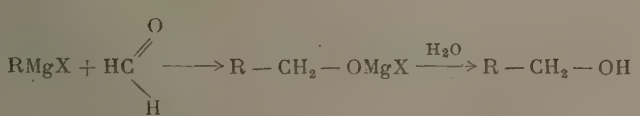
Bekanntlich reagiert Äthylenoxyd sehr leicht mit einer ganzen Reihe von Stoffen, die bewegliche Wasserstoffatome besitzen ([1], [2]). Diese Reaktionen, für die viele Beispiele bekannt sind, können durch eine gemeinsame Gleichung ausgedrückt werden:



Für Äthylenoxyd ist aber noch eine andere Reaktion bekannt, die an das chemische Verhalten von Carbonylverbindungen, in erster Linie an das chemische Verhalten des Formaldehyds erinnert. Hierher gehören die Umsetzungen, die zwischen Äthylenoxyd und Grignard-Verbindungen verlaufen und zu primären Alkoholen führen ([3]):



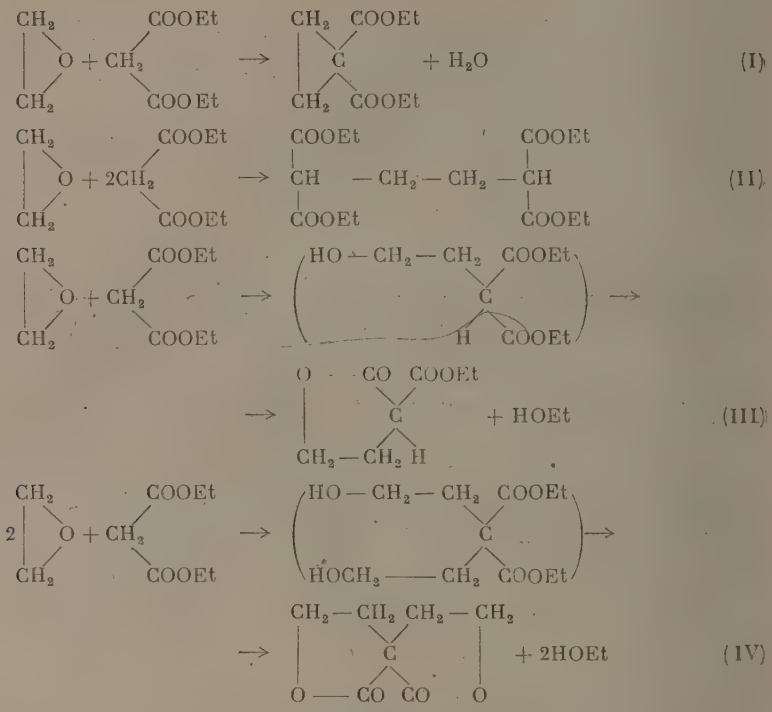
Ähnlich verläuft die Umsetzung zwischen Formaldehyd und Grignard-Verbindungen:



Letztere Gegenüberstellung führte zu dem Gedanken, das Verhalten des Äthylenoxyds bei typischen Aldehydreaktionen zu prüfen. Als typische Aldehydreaktion kann die Knövenagelsche Reaktion betrachtet werden ([4]).

Falls eine Umsetzung zwischen Äthylenoxyd und einem Stoff mit beweglichen Wasserstoffatomen der Methylengruppe eintreten würde, so könnte man in Anlehnung an den Reaktionsverlauf zwischen Formaldehyd und Malonester eine Reihe von möglichen Endprodukten erwarten. Als Verbin-

dung mit beweglichen Wasserstoffatomen der Methylengruppe wurde Malonester gewählt:



Die nach (I) und (II) verlaufenden Umsetzungen sind vollkommene Analoga der Knövenagelschen Reaktion (Methylenmalonester und Methylenbis-malonester), während die nach (III) und (IV) verlaufenden Umsetzungen Anlagerungen des Äthylenoxyds an Malonester sind.

In der Literatur konnten keinerlei Hinweise auf derartige Umsetzungen des Äthylenoxyds mit Stoffen, die bewegliche Wasserstoffatome der Methylengruppe (wie z. B. Malonester) besitzen und die in Gegenwart sekundärer Basen verlaufen, gefunden werden.

Ein Vorversuch zeigte, dass sich Äthylenoxyd mit Malonester in Gegenwart von Piperidin umsetzt. Dieses ist daran zu erkennen, dass nach Stehenlassen des Reaktionsgemisches während 24 Stunden bei Zimmertemperatur, dieses bedeutend viskoser geworden war. Nach fünftägigem Stehen begann eine Abscheidung von farblosen Kristallen aus dem Reaktionsgemisch. Nach dem Umkristallisieren aus Alkohol zeigten diese Kristalle einen Schmelzpunkt von 110°. Die Substanz ist leicht löslich in heissem Wasser und heissem Alkohol. Bezeichnend ist, dass die Substanz selbst in heisser Sodalösung unlöslich ist, während Alkalien leicht lösen. Aus diesen alkalischen Lösungen fällt die Substanz nach dem Ansäuern unverändert aus, was an Schmelzpunkt und Mischschmelzpunkt zu erkennen ist. Letztere Eigenschaft weist auf das Vorhandensein eines Laktons hin. Die Titration ergab Werte, die sehr genau für ein spyrocyclisches Lakton, das gemäss Gleichung (IV) entstanden sein könnte, passten.

Ein solches Dilakton ist von Leuchs und Gieseler [5] durch Umsetzung des Dinatriummalonester mit dem Acetat des Bromhydrins, in einer Aus-

beute von 11% dargestellt worden. Dieses Dilakton schmolz bei 109—110°. Nach Löslichkeit und Kristallform waren beide Substanzen identisch. Damit bestand kein Zweifel an der Identität dieser Verbindungen, umsomehr, als unter sämtlichen, nach Gleichung I bis IV entstehenden Substanzen nur das in Frage kommende Dilakton kristallin ist. Cyclopropandicarbonester (1.1) ist flüssig, Sp. 213° [5]; α,α-Dicarbäthoxy-Adipinsäureester ist ebenfalls flüssig, Sp. 240—245° [6], und α-Carbäthoxy-Butyrolakton stellt eine Flüssigkeit mit dem Sp. 175°/25 mm [7] dar.

Die nachfolgenden Versuche wurden zwecks Ermittelung der optimalen Bedingungen für die Darstellung des Dilaktons unternommen.

Es zeigte sich, dass die höchste Ausbeute an Dilakton dann erreicht wurde, wenn die angewandten Mengen des Malonesters und des Äthylenoxyds den in Gleichung (IV) gegebenen Verhältnissen nahe kamen. Ein geringer Überschuss (etwa 10%) gegenüber der theoretisch erforderlichen Menge an Äthylenoxyd steigert die Ausbeute.

Als Katalysator kann mit gleichem Erfolg sowohl Piperidin als auch Diäthylamin verwendet werden. «Triäthanolamin» ist ebenfalls anwendbar, obwohl hierbei die Ausbeuten beeinträchtigt werden. Piperidin ist als Katalysator gänzlich unbrauchbar. Die Menge des Katalysators beeinflusst stark die Reaktionsgeschwindigkeit. So z. B. ist bei Zimmertemperatur bei Gegenwart von etwa 6% Katalysator die Umsetzung innerhalb von 10 Tagen beendet, während bei einem Zusatz von nur 1.5% Katalysator die Umsetzung etwa einen Monat dauert. Ausbeuten über 86% d. Th. konnten nicht erreicht werden. Da in dem Reaktionsgemisch kein Malonester mehr nachzuweisen ist, so wird offensichtlich ein Teil des Malonesters zu Nebenreaktionen verbraucht. Über diese Nebenreaktionen soll gesondert berichtet werden.

Die Umsetzung zwischen Malonester und Äthylenoxyd verläuft folgendermassen: nach Zusammenbringen der Reaktionsteilnehmer tritt vollkommene Lösung ein (ca 6% Katalysator). Meistens hat sich am folgenden Tage im Reaktionsgefäss (eine starkwandige Flasche) eine ölige Schicht abgeschieden, die jedoch bald wieder in Lösung geht. Am zehnten Tage tritt spontane Selbsterwärmung ein, die 70—80° erreicht, und sofort beginnt reichliche Abscheidung des kristallinen Dilaktons. Weiteres Stehenlassen des Reaktionsgemisches ergibt keine Steigerung der Ausbeute. Ein derartiger Reaktionsverlauf wurde wiederholt beobachtet.

Die lange «Inkubationszeit», die der spontan verlaufenden Reaktion vorangeht, weist darauf hin, dass diese Umsetzung zu den Kettenreaktionen gerechnet werden muss.

Um die Reaktionsdauer zu verkürzen, wurde die Umsetzung bei erhöhter Temperatur in einem Autoklaven vorgenommen. Die im Autoklaven ausgeführten Versuche ergaben jedoch, dass es zwar möglich ist, die Reaktionsdauer zu verkürzen, dass dabei aber die Ausbeute an Dilakton stark sinkt. Eine hervorragende Bedeutung kommt der Versuchstemperatur zu. So ergaben Versuche, die bei Temperaturen von nicht über 110—115° ausgeführt wurden, noch Ausbeuten an Dilakton bis zu 20%. Bei höheren Temperaturen konnte überhaupt kein Dilakton erhalten werden, obwohl nachweislich der gesamte Malonester verbraucht wurde. Es wird also über 115° eine Nebenreaktion zur Hauptreaktion.

Bei einem Versuch, der bei 80° ausgeführt wurde, konnte beobachtet werden, dass nach 3-stündigem Erwärmen, während welcher Zeit der Druck im Autoklaven nahezu konstant blieb, eine momentane Drucksteigerung von 8 Atm. auf 15 Atm. eintrat. Hiernach sank der Druck innerhalb 10 Min. auf 2 Atm. Die Temperatur im Autoklaven stieg ebenfalls stark an (von 80° auf 130°). Anscheinend trat nach einer gewissen «Inkubationszeit» spontane Reaktion ein, die zur starken Selbsterwärmung Anlass gab. Vorher-

gehende Versuche hatten jedoch ergeben, dass die Temperatur von etwa 110—115° für diese Umsetzung kritisch ist, d. h. oberhalb dieser Temperatur kann kein Dilakton erhalten werden. Es liegt nahe anzunehmen, dass auch in den übrigen Versuchen, die im Autoklaven ausgeführt wurden, eine beträchtliche Selbsterwärmung die Ursache der sehr bescheidenen Ausbeuten ist.

Das Überhitzen der Reaktionsmasse beeinflusst lediglich den Reaktionsverlauf, da bereits gebildetes Dilakton so temperaturbeständig ist, dass es ohne Zersetzung unter gewöhnlichem Druck destilliert werden kann.

Es bleibt somit als einzig brauchbares Darstellungsverfahren des Dilaktons, die Umsetzung bei Zimmertemperatur, ungeachtet dessen, dass hierbei die Reaktion etwa 10 Tage erfordert. Versuche, die Reaktionsdauer durch Erwärmung zu verkürzen, ergaben keine brauchbaren Resultate.

In theoretischer Hinsicht ist diese Umsetzung dadurch bemerkenswert, dass diese, obwohl sie als typische Anlagerungsreaktion zu werten ist, stark an die Knövenagelsche Reaktion erinnert.

Anlagerungen von Verbindungen mit beweglichen Wasserstoffatomen der Methylengruppe an doppelte Bindungen sind in genügender Anzahl bekannt [8]. Die Anlagerung von Malonester an Äthylenoxyd unter Bedingungen der Knövenagelschen Reaktion werden erstmals beschrieben.

Die beschriebene Umsetzung, die zum Dilakton der 1.5-Dioxy-Propan-3.3-Dicarbonsäure führt, ist gegenwärtig die einzige Methode, die es gestattet, mit guter Ausbeute in den Malonester gleichzeitig zwei β-Oxyäthylreste einzuführen. Die früher von Leuchs und Gieseler vorgeschlagene Arbeitsmethode liefert durchaus unbefriedigende Ausbeuten. Verhältnismässig leicht gelingt es nach Traube und Lehmann in den Malonester einen β-Oxyäthylrest einzuführen, dagegen gelingt nach dieser Methode die Einführung eines zweiten β-Oxyäthylrestes in den Malonester nicht.

Die Untersuchung wird auf andere Verbindungen mit beweglichen Wasserstoffatomen der Methylengruppe fortgesetzt.

Beschreibung der Versuche. Ein Vorversuch wurde in einer dickwandigen Flasche von 50 cm³ Inhalt ausgeführt. 16 g Malonester, 9 g Äthylenoxyd (0.2 Mol.) und 2 g Piperidin wurden in die Flasche gefüllt, die durch einen am Flaschenhals mit Draht festgebundenen Gummistopfen verschlossen wurde. Am anderen Tage hatte sich im Reaktionsgemisch eine ölige Schicht abgeschieden, die jedoch bald darauf wieder in Lösung ging. Nach 3-tägigem Stehen scheideten sich Kristalle ab, deren Menge nach 5 Tagen nicht mehr zunahm. Die schwach rosa gefärbten Kristalle wurden abfiltriert, mit Alkohol gewaschen und getrocknet; Ausbeute 9 g (etwa 43% d. Th.); Schmp. 108—109°. Nach dem Umkristallisieren aus heissem Alkohol wurden farblose Kristalle vom Schmp. 110° erhalten. Diese Substanz besitzt grosses Kristallisationsvermögen, und beim langsamen Kristallisieren können mühelos sechseckige Blättchen bis zu 1 cm Durchmesser erhalten werden.

0.1773 g bzw. 0.1681 g Substanz verbrauchten 22.65 bzw. 21.40 cm³ 0.1 *n* NaOH.

$C_7H_8O_4$: gefunden 57.5% bzw. 57.2%; berechnet 57.5%.

Die Versuche zur Darstellung des Dilaktons wurden wiederholt, um die optimalen Bedingungen für die Darstellung des Dilaktons festzustellen, sowie um die Rolle des Katalysators zu ermitteln. Die Versuchsergebnisse sind in nachstehender Tabelle zusammengestellt, ebenso wie die Ergebnisse derjenigen Versuche, die im Autoklaven ausgeführt wurden. Letztere wurden in einem rotierenden Autoklaven von 400 cm³ Inhalt ausgeführt, der Reaktionsbeginn, sowie die Reaktionsgeschwindigkeit wurden durch Druckänderungen verfolgt, die am Manometer abzulesen waren. Als Ausbeute wurde diejenige Menge des Dilaktons gerechnet, die nach 24-stündigem Stehen des Reaktionsgemisches auskristallisiert war.

Aus der Tabelle geht hervor, dass Piperidin und Diäthylamin gleichwertige Katalysatoren sind, Triäthanolamin wirkt etwas weniger günstig.

Sämtliche Versuche, die im Autoklaven und unter Erhitzen ausgeführt wurden, gaben keine befriedigenden Resultate.

Malonester in g	Äthylenoxyd in g	Katalysator und Menge in g	Versuchsdauer	Ausbeute an Dilakton	Bemerkungen
40	22	Piperidin, 4	5 Tage	31 g—78%	Zimmertemp.
40	22	» 2	10 »	24 g—61%	»
40	25	» 2	10 »	25 g—64%	»
40	30	» 2	10 »	23 g—59%	»
40	22	» 4	5 »	*	»
40	22	Diäthylamin, 4	5 »	*	»
40	22	» 2	10 »	25 g—64%	»
40	22	» 1	20 »	18 g—46%	»
40	22	Triäthanolamin, 2	15 »	15 g—38.5%	»
40	22	Piperidin, 2	20 »	**	»
40	22	» 1	4 St.	6.5 g—26%	Autoklav 100°
40	22	» 1	3 »	5.4 g—21%	» 110°
40	22	Diäthylamin, 1	3 »	—	» 120°
40	22	» 1	3 »	—	» 115°
40	22	» 2	3 »	***	» 80°
40	22	Piperidin, 2	3 »	***	» 80°
16	100	» 5	10 Tage	135 g—86%	Zimmertemp.
16	100	Diäthylamin, 5	10 »	133 g—85%	»

* Der Flascheninhalt wurde gegen Ende der Umsetzung herausgeschleudert; der Versuch misslang.

** Die Reaktionsmasse war dunkelrot gefärbt; es konnte kein Dilakton erhalten werden.

*** Bei diesen Versuchen konnte spontane Selbsterhitzung bis auf 130° beobachtet werden.

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CHEMIE

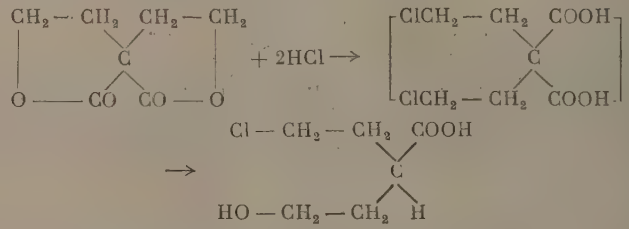
ÜBER DIE EINWIRKUNG VON HALOGENWASSERSTOFFEN AUF DAS DILAKTON DES 1.5-DIOXY-3.3-DICARBOXYPENTANS

Von K. G. PACKENDORFF

(Vorgelegt von N. D. Zelinsky, Mitglied der Akademie, d. 12. IX. 1939)

In der vorhergehenden Mitteilung wurde gezeigt, dass bei der Umsetzung von Malonester mit Äthylenoxyd in Gegenwart von sekundären Aminen mit guter Ausbeute das Dilakton des 1.5-Dioxy-3.3-Dicarboxypentans (Dilakton) entsteht.

Als Ausgangsmaterial wurden 1.5-Dihalogenpentane benötigt. Es wurde beschlossen, dieselben durch Einwirkung von Halogenwasserstoffen auf das Dilakton darzustellen, da zu erwarten war, dass hierbei der Laktonring unter Bildung von 1.5-Dihalogen-3.3-Dicarboxypentan gesprengt wird, die Halogenverbindung aber unter den Reaktionsbedingungen zu 1.5-Dihalogen-3-Carboxypentan decarboxyliert wird.



Es ergab sich jedoch, dass beim Erhitzen des Dilaktons mit konzentrierten Halogenwasserstoffen nur der eine Laktonring unter Decarboxylierung gesprengt wird, sodass nicht 1.5-Dihalogenderivate des Pentans, sondern α-(β-Halogenäthyl)-Butyrolaktone entstehen. Beim weiteren Erwärmen mit Halogenwasserstoffen tritt ebenfalls keine Sprengung des zweiten Laktonringes ein. Wenn eine derartige Ringspaltung bei hoher Temperatur und in Gegenwart eines grossen Überschusses an Halogenwasserstoff vielleicht auch stattfinden würde, so tritt bei niederer Temperatur anscheinend eine Cyclisation ein. Somit sind also α-[β -Halogenäthyl]-Butyrolaktone die einzigen Reaktionsprodukte.

Es wurden Chlor,- Brom- und Jodderivate erhalten, geruchlose Flüssigkeiten, die im Vacuum ohne Zersetzung destilliert werden können.

Beschreibung der Versuche. Beim Erwärmen des Dilaktons mit rauchender Salzsäure im offenen Kolben tritt keine merkliche Reaktion ein. Das Dilakton löst sich dabei vollständig, um beim Erkalten wieder auszukristallisieren. Mehrstündiges

Erhitzen der Reaktionsteilnehmer führt ebenfalls nicht zum Ziel. Die Reaktion wurde daher in zugeschmolzenen Glasröhren, die während 3 Stunden auf 140° erhitzt wurden, ausgeführt. Unter diesen Bedingungen verläuft die Reaktion quantitativ.

15 g des Dilaktons wurden während 3 Stunden mit 30 cm³ konzentrierter Salzsäure auf 140° erhitzt. Nach dem Erkalten hatte sich eine ölige Schicht abgeschieden. Beim Öffnen der Röhre konnte grosser Druck festgestellt werden. Die Reaktionsmasse wurde mit dem gleichen Volumen Wasser versetzt und dreimal ausgeäthert. Die ätherischen Auszüge wurden mit Sodalösung, darauf mit Wasser gewaschen und über $CaCl_2$ getrocknet. Nach dem Verdampfen des Äthers wurde der Rest unter vermindertem Druck destilliert. Sp. 156—157°/28 mm; $n_D^{22} = 1.4746$. Die Ausbeute betrug 13 g, d. h. 91% d. Th.

Unter den gleichen Bedingungen konnten aus 50 g Dilakton (die Reaktion wurde in 3 verschlossenen Röhren ausgeführt) 43 g α-(β-Chloräthyl)-Butyrolakton erhalten werden, was einer Ausbeute von 95% d. Th. entspricht.

0.2365 g Substanz verbrauchten 16.55 cm³ 0.1 *n* $AgNO_3$ (nach Stepanow).

$C_6H_9O_2Cl$: gefunden 24.6%, berechnet 23.8%.

20 g Dilakton wurden mit 30 cm³ konstant siedender Bromwasserstoffsäure unter Rückfluss während 4 Stunden bis zum Sieden erhitzt. Zu Beginn der Reaktion konnte Kohlensäureabspaltung beobachtet werden, die aber bald darauf nachliess. Das aus dem dunkel gefärbten Reaktionsgemisch abgeschiedene Öl wurde wie oben aufgearbeitet. Das erhaltene Produkt siedete bei 168—169°/25 mm; $n_D^{21} = 1.5230$.

0.1124 g Substanz verbrauchten 5.8 cm³ 0.1 *n* $AgNO_3$ (nach Stepanow).

C_6H_9OBr: gefunden 41.2%, berechnet 41.5%.

20 g Dilakton wurden im Laufe von 4 St. mit konstant siedender Jodwasserstoffsäure erhitzt. Zu Beginn der Reaktion trat Kohlensäureabspaltung ein. Die Reaktionsmasse wurde ausgeäthert und die ätherische Lösung mit Sodalösung, verdünnter Bisulfitlösung und darauf mit Wasser gewaschen und getrocknet. Das gelbliche Reaktionsprodukt siedete bei 178—180°/25 mm; 154°/5 mm.

0.1623 g Substanz verbrauchten 6.7 cm³ 0.1 *n* $AgNO_3$ (nach Stepanow).

$C_6H_9O_2J$: gefunden 52.3%, berechnet 52.8%.

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CHEMISTRY

LIBERATION OF TOXIC GASES IN THE EXPLOSION OF INDUSTRIAL EXPLOSIVES

By K. K. ANDREEV and M. M. PURKALN

(Communicated by A. A. Skochinsky, Member of the Academy, 11. VII. 1939)

In explosions of industrial explosives, toxic gases form part of the gases liberated. If the explosive used contains derivatives of nitric acid (ammonites and dynamites), the chief toxic gases are carbon monoxide and nitrogen oxides. The liberation of toxic gases is of great importance when the explosives are intended for underground mining operations. The explosion products in this case are mixed with the air in the mine, and if ventilation is insufficient, may lead to chronic and even acute poisoning of the miners.

The method employed until recently for determining the amount of toxic gases liberated by explosives consisted in exploding a freely suspended charge weighing 100 g inside of an evacuated steel bomb of 15 or 50 l (1) capacity. This method gave results showing very small amounts of nitrogen oxides liberated from ammonites and dynamites commonly used in the USSR (to 5 l/kg). The quantity of CO evolved did not exceed 44 l/kg (2). According to the usual method of computing the amount of liberated toxic gases (i. e. the volume of CO+10 times the volume of nitrogen oxides, in view of their greater toxic value), this means that the gases liberated by these explosives did not exceed 50 l. This figure was taken as a basis for designing the ventilation necessary in mines.

In 1934, Romanov (3) published the results of experiments conducted in mines which have shown, that when the charge was exploded in the rock, it gave an amount of nitrogen oxides much greater than the bomb experiments. His results showed that 5 l of NO_2 were liberated as the mean by 62% gelatine-dynamite and 15 l by ammonite No. 2.

Unfortunately, Romanov's results were not given the importance they deserved, and it was not until 1937 that the Soyuzvzryvprom arranged similar experiments which fully confirmed the results obtained by Romanov. Attempts to determine the effect of different factors upon the volume of toxic gases liberated by the explosives (position of the primer, efficiency of the charge, quality of stemming, etc.) failed to give any satisfactory results in these experiments, probably because the methods adopted were not sufficiently developed, since experiments made under the same conditions gave widely different results (4).

Simultaneously with these experiments, Suvorov succeeded in establishing that it is possible to obtain large volumes of toxic explosion products

in a laboratory bomb. It was only necessary to cover the charge with a thick layer of ore or sand. In agreement with the results obtained in the mines, the equivalent volume of toxic gases liberated amounted to as much as 500 l ([5]).

Naturally enough, the most radical method to avoid the discrepance between the actual amount of toxic gases liberated and the capacity of the mine ventilation should be to find explosives which would give considerably smaller volumes of toxic gases.

The present investigation was directed to this aim. Two groups of ammonites, very near in composition to ammonite No. 2 (12% of trotyl and 88% NH_4NO_3) were tested. One group of ammonites differed from ammonite No. 2 only in that the components were used in more rational proportions; the other group included some finely divided wood meal in their composition. The effect of preparing the components and the thoroughness of the mixing operation were also investigated.

In the experiments dealing with the effect of changing the composition of the explosive, all variables that could be expected to affect the results were kept constant. Thus, mixing was effected in an octagonal drum having sides 11 cm wide and rotating at a velocity of about 60 turns per minute. The fineness of the powdered materials was close to industrial values*. Through the sieves No. 16 (0.4×0.4 mm mesh) and No. 49 (0.12×12 mm) pass: for NH_4NO_3—100 and 21—27%, for trotyl (m. p. 80.8°)—100 and 4%, and for the wood meal (from dried birch)—100 and 10%, respectively.

The volume of explosion products was measured with the help of a 50-g charge wrapped in paper (1.25 g) and exploded by a No. 8 electric detonator in a paper shell, the charge being surrounded by a layer of quartz sand 1 cm thick and weighing about 230 g. The explosion took place in a bomb of 17.25 l capacity evacuated to $p=40$ mm Hg. The volume of the explosion products was calculated from the pressure reading made one hour after the explosion. The volume of CO_2 was determined by absorbing it in a 30% solution of KOH; NO, by absorption in a saturated solution of $FeSO_4$ acidified by the addition of a little sulfuric acid; CO, by absorption in an ammoniacal solution of copper chloride; CH_4 and H_2, by burning; NO_2 was determined by Griess' colorimetric method in the solution used to absorb CO_2; it was assumed that NO was absorbed simultaneously according to the reaction ([6]):

$$N_2O_3 + 2\,KOH = 2\,KNO_2 + H_2O.$$

The results of these experiments are given in Table 1. They show that the volume of toxic gases is highly dependent on the composition of the explosive. Doubling the proportion of the most active explosive component (trotyl) reduced the volume of nitrogen oxides by more than 10 times, at the same time increasing the volume of CO twice (see results of experiments 1—2 and 7—8). The total equivalent volume of the poisonous gases (taking the coefficient 10 for the nitrogen oxides**) is thus reduced 3½ times. When 4% of the ammonia nitrate is replaced by wood meal, the volume of the nitrogen oxides is reduced (though to a lesser extent with the addition of trotyl) and that of carbon monoxide increased. The two ternary compositions which were studied showed thus a reduction in the total equivalent volume, but not to the same extent as the binary mixtures investigated.

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* Cf. All-Union Standard for ammonites No. 4117.

** The question of the numerical relation between the toxic effect of nitrogen oxides and carbon monoxide, and the validity of the use of the total equivalent volume as a criterion of the dangerousness of toxic explosion products has not yet been definitely settled.

Table 1

Effect of Varying Composition of Ammonite on Production of Toxic Gases

Exper. No.	Composition of ammonite, %			Volume of toxic gases (l/kg of explosive)					
	Trotyl	Ammonia nitrate	Wood meal	$NO+NO_2$	Average	CO	Average	Total CO+10 ($NO+NO_2$)	Average
1	12	88	—	29.3	29.3	37.7	35.2	330.7	328
2				29.3		32.6		325.6	
3	15	85	—	20.3	18.9	36.3	34.8	239.3	224
4				17.5		33.2		208.2	
5	21.3	78.7	—	8.9	8.3	49.5	47.9	138.5	130
6				7.6		46.3		122.3	
7	25	75	—	2.6	2.4	—	67.7	—	92
8				2.2		67.7		89.7	
9	12	84	4	20.2	19.1	38.5	35.7	240.5	226
10				17.9		32.9		211.9	
11	15	81	4	10.1	10.3	46.8	48.4	147.8	151
12				10.4		50.0		154.0	
13	18.4	77.6	4	5.4	5.4	59.8	57.6	113.8	111
14				5.3		55.5		108.5	

Note. Moisture in compositions from 0.03 to 0.15%. Amount of NO_2 in exp. 1—14 varied from 0.02 to 1.1 l.

The next series of experiments was made to determine the effect of varying the fineness of the ingredients (ammonia nitrate and trotyl) on the formation of toxic gases. For this purpose three ternary compositions and a binary one were prepared with three degrees of fineness of two main ingredients. In the first, these components passed through a No. 16 sieve, in the second, through a No. 49 sieve and in the third, through a No. 73 sieve (mesh 0.08× ×0.08 mm).

The results given in Table 2 show the enormous effect of the degree of fineness of the ingredients.

Increasing the fineness of the ingredients from sieve No. 16 to No. 49 in the case of experiments 1—4 and 5—10 in Table 2 reduced the nitrogen oxide practically to zero. Further comminution of the ingredients caused only a slight decrease in the volume of the nitrogen oxides. For the case of ammonite No. 2, the increased fineness of the ingredients from sieve No. 16 to sieve No. 49 also caused a reduction in the volume of nitrogen oxides liberated, but to a much lesser extent—to about twice as little. The fineness of the ingredients had practically no effect upon the volume of CO.

A further series of experiments was directed to determine the effect of comminuting each of the two main ingredients separately (Table 3).

Table 3 shows that when one of the ingredients is coarsely ground, more of the nitrogen oxides are formed than this is the case when both are finely comminuted. The more important, as will be seen from comparing experiments 2 and 3, is the fineness of the trotyl.

Table 2

Effect of the Degree of Fineness of Ingredients on Production of Toxic Gases

Exper. No.	Degree of fineness (sieve No.)*	Composition of ammonite, %			Volume of toxic gases (l/kg of ammonite)					
		Trotyl	Ammonia nitrate	Wood meal	$NO+NO_2$	Average	CO	Average	Total CO+10 ($NO+NO_2$)	Average
1	16	18.4	77.6	4	5.4	5.4	59.8	57.7	113.8	111
2					5.3		55.5		108.5	
3	49	18.4	77.6	4	—	0.12	63.0	60.0	63.0	61
4					0.25		56.4		58.9	
5	16	15	81	4	10.1	10.3	46.8	48.4	147.8	151
6					10.4		50.0		154.0	
7	49	15	81	4	0.3	0.15	40.6	40.1	43.6	42
8					—		39.5		39.5	
9	73	15	81	4	—	—	40.7	40.4	40.7	40
10					—		40.0		40.0	
11	16	12	84	4	20.2	19.0	38.5	35.7	240.5	226
12					17.9		32.9		211.9	
13	49	12	84	4	6.3	6.1	37.6	35.6	100.6	96
14					5.8		33.7		91.7	
15	73	12	84	4	5.8	5.2	35.3	34.7	93.3	87
16					4.6		34.1		80.1	
17	16	12	88	—	29.3	29.3	37.7	35.2	330.9	328
18					29.3		32.6		325.6	
19	49	12	88	—	14.4	15.9	31.5	29.1	175.5	188
20					17.3		27.3		200.3	
21	73	12	88	—	13.3	13.4	26.2	29.6	159.2	163
22					13.4		33.0		167.0	

Note. Moisture in compositions not greater than 0.3%. * Number of sieve through which ingredient passes completely.

The study of the effect of the ammonite humidity has shown that for the ammonites 25/75 and 18.4/77. 6/4 (sieve No. 16) an increase of the amount of toxic gases is appreciable with a water content of ~5% only. For the amounts 15/81/4 (sieve No. 49) the influence of the humidity is more pronounced; at the content of H_2O of 0.0, 0.5, 3 and 5% the amount of toxic gases equals 42, 46, 57 and 88 l, respectively.

It did not seem worth while to study the effect of varying the degree of mixing of the ingredients, since it is difficult to reproduce in a laboratory the conditions which prevail when ammonite is manufactured in a work. In view of this, only two experiments were made with an ammonite containing 18.4% trotyl and 4% wood meal, the remainder being NH_4NO_3 (sieve No. 16). In one experiment the ingredients were mixed for 6 hours; in the

Table 3

Effect of the Degree of Fineness of Trotyl and Ammonia Nitrate Comprising an Ammonite (of the composition: trotyl 15%, NH_4NO_3—81%, wood meal 4%) on the Liberation of Toxic Gases

Exper. No.	Degree of fineness (sieve No.)*	$NO+NO_2$	Average	CO	Average	Total CO+10 ($NO+NO_2$)	Average
1	Trotyl, 16	10.1		46.8		147.8	
	NH_4NO_3, 16		10.3		48.4		151
	Wood meal, 16	10.4		50.0		154.0	
2	Trotyl, 16	6.2		41.0		103.0	
	NH_4NO_3, 49		6.5		42.0		107
	Wood meal, 16	6.7		43.0		110.0	
3	Trotyl, 49	3.1		41.1		72.1	
	NH_4NO_3, 16		3.9		40.3		79
	Wood meal, 16	4.6		39.4		85.4	
4	Trotyl, 49	0.3		40.6		43.6	
	NH_4NO_3, 49		0.15		40.1		42
	Wood meal, 16	—		39.5		39.5	

Note. Moisture not greater than 0.3%. * Number of sieve through which ingredient passes completely.

other, 12 times less. This resulted in the less intimately mixed ammonite producing 19.4 l of nitrogen oxides instead of 5.4 l, and 69.8 l of CO instead of 57.7 l, the volume of poisonous gases thus increasing 2½ times, 111 and 268 l. It is to be presumed, however, that with increased comminution of the ingredients the effect of poor mixing will not be so great.

The determination of the brisance conducted on lead cylinders showed, that compositions producing smaller volumes of toxic gases possessed greater brisance than those producing more gases. An 12/88 ammonite (sieve No. 16) gave a compression of 14.5 mm; an ammonite containing 15% trotyl and 4% wood meal—a compression of 17.5 mm. It should be mentioned that an increase in the degree of fineness which had, as shown above, a great effect upon the production of nitrogen oxides, does not affect the brisance of the latter explosive to any appreciable extent.

The heat of explosion of «low-gas» ammonites is also considerably higher than that of ammonite No. 2. The theoretical value of the heat developed by an explosion of ammonite No. 2, as deduced from the reaction producing no nitrogen oxides, is equal to 720 kg cal./kg. An ammonite containing 15% trotyl and 4% wood meal (experiments 7—8, Table 2) gives a calculated value of the heat of explosion equal to 1010 kg cal./kg, i. e. 1.4 times larger than that of ammonite No. 2. Therefore, the suggested compositions are not only more rational from the point of view of producing toxic gases, but also possess enhanced explosive power.

Our experiments were not directed to a theoretical investigation of the problem. However, the results obtained show that of the explanations of the effect advanced by one of the authors, the most likely one is the hypothesis that nitrogen oxides in excess of the equilibrium concentration are formed owing to the insufficient detonating properties of the explosive, when the detonation wave does not cause the reactions to develop to the equilibrium

condition. It is still an open question whether this is accompanied by the formation of gaseous products of the primary reaction or of particles of the solid ingredients. The rapid loss of heat on the extensive surface of the sand disintegrated by the explosion (or the breaking up of the secondary reaction chains on this surface) retards the further development of the reactions which take place under conditions of an explosion of a freely suspended charge not encased in ore.

It stands, therefore, to reason that the increase in the reactivity of a heterogeneous mixture, produced by greater comminution of the ingredients, materially assists in bringing the composition of the products of explosion to a state of equilibrium.

Summing up, it is necessary to note that the chief type of ammonite at present in use (88% ammonia nitrate+12% trotyl) is not rationally composed from the point of view of both amount of toxic gases liberated and explosive power developed. It was adopted owing to the wide spread and, as is now known, fallacial belief in the beneficial effect of an excess of oxygen in the explosive on the production of toxic gases. Furthermore, the gas production of ammonite No. 2 is aggravated by bad manufacturing.

The application of a correct method of preparing the ingredients and the use of more rational compositions result in an increase in the explosive power and a reduction of 5 to 8 times in the volume of toxic gases produced in comparison with ammonite No. 2.

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GEOCHEMISTRY

ON THE INTERACTION OF GOLD WITH TELLURIC AND SELENIC ACIDS

By O. E. ZVIAGINCEV and E. A. YAKOVLEVA

(Communicated by A. E. Fersman, Member of the Academy, 12. IX. 1939)

In the oxidation zone of gold-bearing veins fusion of gold usually takes place. The gold is then carried away by descending water stream to the zone of cementation where it is deposited again ([1],[2]). This process accounts for the secondary enrichment of gold deposits in the near-surface zones and the decrease of the gold-content with the depth.

The possible solvents of gold in the oxidation zone may be: a) sulphuric acid in the presence of chlorine, b) telluric acid, c) selenic acid, d) iron sulphate solutions and e) organic substances.

The first and last of the above reagents are positively present, and their effect should be considered as experimentally proved. On the contrary, the influence of iron sulphate solutions on the gold has not been shown experimentally. The solubility of gold in selenic and telluric acids, which may be formed in the course of oxidation of minerals containing tellurium and selenium, has not been established by way of experiment; the absence of any effect of these acids on the gold has not been established either.

The object of this work was to solve this question. The experiments were conducted under the folowing conditions. A 100-ml flask with a hydraulic stopper was placed into a thermostat, in which a definite temperature was maintained by means of a thermoregulator. The flask was filled with 10% solution of telluric and selenic acids, and a glass rod with a hook at one end was plunged into the liquid, with a gold disc suspended at the hook. The rod with the gold disc was set into rotatory motion and served as a stirrer for the solution. Before the experiment the disc was thoroughly washed, ignited and weighed. After the experiment the gold disc was weighed again.

The following experiments were made with a 10% telluric acid solution: a) at 25° for 240 hours, b) at 60° for 240 hours, c) at 100° for 240 hours.

The weight of the gold disc (1.3442 g) remained unaltered in all the experiments. Then the solution flask was transferred from the thermostat to an autoclave, where the solution was stirred for six hours at 150°; the weight of the gold plate remained as before.

Similar experiments were made with a 10% solution of selenic acid and gave similar results, i. e. the gold remained unsolved.

Thus, metallic gold should be considered insoluble in selenic and telluric acids, and under natural conditions these acids are no carriers of gold.

The authors tried to prepare artificially $Au_2(TeO_4)_3$. First gold hydroxide was prepared by precipitation with an alkaline solution from auric chloride ($HAuCl_4$). A freshly precipitated and thoroughly washed deposit of $Au(OH)_3$ was acted upon with telluric acid solution: the deposit proved easily soluble and the resulting solution was of a light-yellow colour. Upon evaporation on a water-bath part of the gold was reduced and the remaining part crystallized in the form of yellow crystals of a telluric acid compound. Simultaneously with this compound white crystals were precipitated of an acid which one would not get rid of.

In order to obtain a purer preparation, the gold hydroxide was solved in hot telluric acid in such a way that the quantity of the acid should be insufficient to solve all of the hydrate, and the surplus was filtered off. In this way the presence of free telluric acid in the solution was avoided. The resulting yellow solution was placed into an exsiccator over sulphuric acid and left there, until crystals of the chemical compound were isolated. These were of a yellow colour and an acicular shape. But using this method we also failed to obtain absolutely pure crystals: an admixture of white crystals of telluric acid and reduced mettalic gold was always present. We did not succeed in finding a solvent which would solve one of the substances present in the mixture.

The purest preparations of the compound were analyzed. Gold was determined gravimetrically as a metal; it was precipitated by boiling the solution with oxalic acid. In the filtrate of gold tellurium was precipitated by boiling with hydrazine and a simultaneous saturation of the solution with SO_2. The black tellurium precipitate was filtered off through a Shott crucible, washed with hot water and alcohol and weighed [3].

The results of some of the analyses are given in the table. Evidently, the yellow crystals obtained present a mixture of different compounds containing different quantities of telluric acid and water residues.

Weight	Gold, %	Tellurium, %	Au : Te ratio
0.1700	20.0	19.5	~1 : 1
0.2166	37.0	32.0	~1.1 : 1
0.1994	28.48	8.42	~3 : 1
0.0694	18.52	13.21	~3 : 2
0.1554	18.35	12.5	~3 : 2
Theoretically for $Au_2(TeO_4)_3$	—	—	~1 : 1
» » Au_2TeO_4	—	—	~3 : 1

As a result of this work the following facts have been established: 1) The selenic and telluric acids have no direct effect upon gold. 2) The existence has been established of gold and telluric acid compounds obtained under the influence of this acid on gold hydroxide, but in a pure state these compounds have not been isolated. 3) In nature telluric and selenic acids cannot be carriers of gold.

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GEOLOGY

GENETIC FOUNDATIONS OF THE CORRELATION ACCORDING TO TERRIGENOUS COMPONENTS

By V. P. BATURIN

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During the recent 5—10 years the correlation according to terrigenous components has become firmly established in the practice of Soviet geology, especially of petroleum geology. During this period the possibility of a new branch of stratigraphy (petrostratigraphy) has been revealed, and the solving power of new correlations both in thickness and in strike has been evaluated. On a rather vast material the efficiency of subdividing sections, according to petrographic characters, has been demonstrated, as well as their invariability in large stratigraphical units along the strike, over considerable distances. Along with this, it has become evident how poorly founded was the attempt at a complete identification of petrostratigraphy with biostratigraphy, and of heavy minerals with leading fossils. The peculiarities in the behaviour of minerals and their advantages as compared to correlatives from the organic world have been also revealed.

Along with the introduction of correlations of the terrigenous complex into the practice of prospecting, especially of oil fields, of the part of some investigators attempts were made to found this method of correlation on a theoretical basis. H. B. Milner was the first to give a scheme explaining the appearance of different mineral associations in a sedimentary complex, depending on the difference in the mineral composition of the rocks eroded. As shown by Milner, an «upsetting» of the mineral stratification of the region of denudation and its reverse repetition in the zone of deposition take place. The mineral characteristics of the upper complex of rocks in the region of erosion will characterize the lower beds of the sediments deposited, while the older formations, exposed by erosion later on, will give their minerals to the beds accumulating over those previously formed.

In the «Paleogeography on the base of terrigenous components», aside from Milner's scheme considering the erosion of the static dry land, we have introduced a series of transformations occurring in the region of erosion and influencing the ultimate composition of the denudation product. To these transformations we have referred the effusions of lava, the supply of glacial deposits, the variations in the climatic regime; great tectonic dislocations could be also introduced as supplements. All these processes change the composition of clastic materials within the territory of that distributive province*

* By the distributive province Milner means a certain spatially limited complex, embracing all the rocks (igneous, metamorphic and sedimentary), taking part in the formation of sediment accumulations contemporaneous with it. This formulation, from our

where they are manifested, which is ultimately reflected on the composition of the deposits of the corresponding terrigenous-mineralogical province*.

However, in our text-book quoted above we treated the different changes in the composition of the terrigenous complex from the standpoint of their paleogeographical importance, without especially touching upon the question of correlation. Quite recently we had again to attack the problem of correlation according to the terrigenous components and to inquire into the causes which determine the shaping of series and horizons, individualized by minerals of rock fragments. It seems to us that an analysis of these causes in the form of a working hypothesis is absolutely necessary for a conscious correlation, particularly when the student passes from the correlation of separate bore-holes to that of the sections of whole areas and regions. A formal comparison of the graphs showing the mineralogical composition (often of the heavy minerals only), without considering geological environment and paleogeography, is shown by experience to be the cause of great errors.

Below we present our attempt to systematize the causes determining the heterogeneity of the mineralogical composition in series of sediments.

Heterogeneity inherent in the complex eroded (of the distributive province): a) mineralogical heterogeneity of sedimentary series; b) presence of volcanogenous formations; c) presence of intrusions and complexes of metamorphic rocks.

When the sedimentary rocks are eroded as a result of redeposition, it is the less stable minerals, highly valuable for correlation, that are usually removed. If simultaneously not one but several minerally individualized series are eroded (as it is the case in folded areas), the points of difference fade out, and in the newly deposited sediments the mineral zoning is either slightly pronounced or lost altogether.

Sharply delimitated horizons arise when a volcanic series enclosed in a sedimentary complex free from pyroclastic material begins to erode. Of interest from the standpoint of correlation is also the moment of the exposure of intrusions by erosion, particularly of their upper zone, where the contact processes are active. In this case, in the sediment such rare minerals as topaz, cordierite and others are encountered. The appearance of metamorphic rocks in the zone of erosion is characterized by an extensive development in the sediments of such minerals, as disthene, staurolite, sillimanite.

The heterogeneity of the sediments deposited is produced also by processes changing the aspect of the distributive province simultaneously with its erosion. It seems to us that the following of these processes should be noted: a) effusions of lava and ejections of loose products of eruptions; b) supply of glacial deposits; c) change of climate; d) considerable tectonic dislocations.

Since both the effusions of lavas and the supply of glacial deposits usually affect large areas, these events are reflected in the products of denuda-

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standpoint, should be made preciser, namely, it should be emphasized, that the «spatially limited complex» must be petrographically individual, it not being necessary that this individuality should be based on a profound genetic similarity of the igneous rocks and on their belonging to the same petrographic province. The features of individuality may consist in the proportion of sedimentary, igneous and metamorphic rocks taking part in the composition of a given distributive province, as well as in the special properties of sedimentary rocks, and in other features leaving a typical imprint on the products formed when a given area is denudated.

* The term of terrigenous-mineralogical or simple terrigenous-mineralogical provinces is applied to the areas of sedimentation (both recent and fossil) characterized by one complex of light and heavy minerals and connected with one distributive province. Under a complex terrigenous-mineralogical province we mean areas receiving their material from several distributive provinces.

tion also within a considerable territory and give rise to sharply outlined (especially in the bottom) horizons. Let us note, for example, the appearance (in connexion with Quaternary effusions) of hypersthene in the recent deposits of the Caucasus, as well as in the West-Siberian lowland (E. V. Shumilova).

With the spreading of the mantle of glacial deposits over the Great Russian Plain, a migration of metamorphic minerals from the Fennoscandinavian Shield southward is connected. These minerals are widely spread in the Quaternary deposits from the Pechora to the Caspian Sea.

The changes of the climatic environment, resulting in the change of the regime of weathering, may be the cause of either the retention of some unstable minerals, or their destruction, which will undoubtedly tell upon the composition of the sediments formed synchronously with them.

The tectonic process in the shape of widely spread elevations causes a rejuvenation of the relief and a successive erosion of older and older complexes. Of independent value may be large dislocations in the shape of overthrusts and large faults, with which is connected the introduction into the zone of erosion of new locally spread rocks and the appearance in the sediments of the minerals enclosed in them.

The above-listed factors, determining the substitution of one mineralogical composition by another, are the features of areas of denudation—distributive provinces; however, we would make a serious mistake, if we failed to consider the nature of sedimentation and the regime of transportation, influencing also the heterogeneity of the mineralogical composition of time. Of these processes, the following should be noted: a) the pulsation of different sources of denudation and b) the change of vectors of the forces of transportation in value and direction.

It is not unfrequent that sediments are carried in at once from several distributive provinces; the areas of sedimentation corresponding to them we name the complex terrigenous-mineralogical provinces. As an example we may cite the predeltaic space of the Terek river, undoubtedly reached by the alluvium of the Volga. From several sources were formed the Quaternary deposits of the central part of Holland, as shown by the detailed investigations of C. H. Edelman. The irregular action of the different sources supplying the sediments of a different composition will bring about the formation of horizons characterized by distinct terrigenous associations. A similar setting will, most probably, account for the petrostratigraphy of the productive series of the Pirsagat region and South Kabristan (Azerbaidjan), where the lower part of the above-noted complex is characterized by a mineral association which we have named the Kabristan one (epidote, zircon, tourmaline, garnet), and the upper part, by the Kura association (monoclinic pyroxenes, hornblendes). The source of the Kabristan association of minerals was the eastern extremity of the Main Caucasian Range. The association of monoclinic pyroxenes and hornblendes was derived from the volcanogeous series of the Main Range and Minor Caucasus and was transported by the Paleokura, a water artery whose basin was near the present Kura. This river at the age of the productive series was discharging into a deep bay projecting into the Kura depression; as the filling of this bay with the deposits of the Paleokura proceeded, its delta moved eastward, and in the second half of the age of the productive series the Paleokura sediments began to be deposited in the region of South Kabristan and the Pirsagat region, where previously only products coming from the side of the eastern extremity of the Main Caucasian Range were deposited. Sporadically, to the same region came also the alluvial of the artery whose delta was in the north (the Paleovolga), on which point we shall not dwell at greater length.

The evolution of the dynamics of the basin of sedimentation itself is also reflected upon the composition of sediments. The changes of velocities of the transporting agents will be first of all reflected on the mechanical composition, and the latter, as it is known, is related to the mineralogical composition. The seasonal nature of the mineral associations noted by E. W. Ellsworth and W. L. Wilgus in the summer and winter layers within the series of banded clays of Wisconsin, was probably related to the different velocities of transportation.

The secular changes of the climate may cause the evolution of the terrigenous complex also in series of considerable thickness; however, it is hardly probable that they produce cardinal changes.

Considerably more serious transformations in the composition of the sediments are produced by the change of the direction of the agents of transportation, of currents in the first place. With the modern scheme of currents in the South Caspian region the alluvium of the Kura moves southward, and to the north of Cape Byandavan the chief elements of the Kura—monoclinic pyroxenes and hornblendes—are comparatively seldom found in the sediments. If the direction of the currents changed and began to move from the south to the north, in the zone north of Cape Byandavan, upon silts and sands, containing almost no pyroxene and hornblendes, sediments containing an abundance of these minerals would be deposited.

It is highly probable that the phenomena described do not exhaust all the factors responsible for the change of the mineralogical composition within the sediments formed; however, it is doubtless that these phenomena must be taken into consideration in the first place when analyzing any correlation scheme. If the student succeeds in distinguishing within the diverse processes those which are fundamental in the given paleogeographical environment, he is sure to profit by them much better than by a mere mechanical comparison of graphs of composition of the terrigenous complex.

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GEOLOGY

ON THE AGE OF THE SERPENTINITES OF THE CAUCASIAN RANGE

By N. E. EFREMOV

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The question of the age of the Caucasian hyperbasites and the products of their metamorphization—the serpentinites—is surely one of the most important questions for the Caucasian geologists, inasmuch as it is most intimately connected with the question of the age of acid and basic intrusions usually associated with serpentinite intrusions.

The latter question is of both scientific and practical importance, since it is connected with the metallogeny of the Caucasian Range. While conducting in the current year a detailed investigation of the Caucasian serpentinites, the author was able to make certain observations, the results of which are of considerable interest. These observations bring a fundamental change into the conceptions which prevailed. The authors of the existing articles, most of which are mere compilations, usually point to the fact that no serpentinite pebbles have ever been found neither in the Permian, nor Carboniferous conglomerates of the Caucasus (the only exception is presented by the observations of G. E. Piliuchenko). At the same time an eruptive contact has been reported of the serpentinites with the Permian (Nijnaya Teberda, Khudess, etc.) and the Carboniferous (Zaguedan, Khudess, etc.). Owing to this, some authors referred the serpentinites to the Permian or even post-Permian time, while others without sufficient grounds determined the age of the intrusions as pre-Cambrian, or Caledonian.

Our investigations have shown that in the conglomerates of the Middle Carboniferous in the river system Kefar (Kumbizh gully), Kefar-Agur, Zaguedan, Khudess serpentinite pebbles are encountered everywhere.

It is most important to note that in individual areas (Kumbizh gully, Zaguedan creek) a basal conglomerate may be clearly seen, consisting throughout of serpentinite boulders and pebbles, cemented by an altered serpentinite cement. Higher up this horizon is replaced by beds of grey Carboniferous conglomerates, filled with serpentinite pebbles. We are enabled to speak here not only of individual serpentinite pebbles, but of vast accumulations, since the thickness of the grey conglomerate beds along the Kumbizh gully is above a hundred meters. Within the same area along the right bank of the Kefar River the serpentinites are overlain by sandstones and schists of the Middle Carboniferous. Consequently, the upper age limit of the principal hyperbasite intrusions of the Caucasus, which produced the serpentinites,

is established as pre-Middle Carboniferous. The regional character of this phenomenon has been proved by our observations.

In order to solve the question as to the lower age limit of the principal serpentinite intrusions, the following facts may be cited. The serpentinites of the Malka, Guidam, Kefar, Kefar-Agur, Bolshoy Zelenchuk, Azgara, Azhoga, Zaguedan, Beden, Blyb and other break through the metamorphic beds of the Lower Paleozoic—chiefly, different metamorphic schists and limestones. It is quite evident that in order to establish a definite lower age limit of the intrusion, it was necessary to study those areas of serpentinite outcrops which break through the deposits of different paleozoic systems. In general the fact is to be noted that the largest serpentinite massifs are fixed within those areas, where Paleozoic fields are preserved and in particular Carboniferous covers, which is easy to understand. One of these areas—the Nijne-Teberda—was visited by the author together with V. N. Robinson, an expert in the geology of the Caucasus. As a result of this study it has been established that the serpentinites break here through the deposits of the Lower Carboniferous (the Karachaev series, according to V. N. Robinson), represented by sandstones and schists. Proceeding from the monotypical composition of the serpentinite intrusions of Teberda, Beden, Khudess, Kefar, Kefar-Agur, Bolshoy Zelenchuk, Zaguedan, etc., we regard them as being of the same age, and thus we come to establish their very narrow age limits between the Lower and Middle Carboniferous.

In this way the Caucasian ultrabasite intrusion which produced a number of basic, most extensive, now almost completely serpentinized massifs (the Kefar-Zelenchuk, Zaguedan, Teberda, Guidama, Khudess, as well as the Beden, Malka and Tkhach) was referred to the Lower Carboniferous. The latter statement is most conclusively consistent with all known observations of different investigators of the Caucasus who studied the serpentinites of this country.

It should be mentioned here that the Caucasian serpentinites are in general formations of a different age. Among these pre-Cambrian serpentinites may be distinguished, the serpentinite outcrops at the Daut pass, at the Markopidze and higher up the Daut being typical representatives of these. From the author's observations it has been definitely established that the former are xenolith-like bodies enclosed by those granitoids which are represented at present by gneissose rocks, among which occur the serpentinites. The existence of typical contact-metamorphic formations, represented by hornblende, talc and micaceous fringes, as well as the presence of «amphibole bombs» in the gneissic granitoids show beyond doubt that the serpentinites have been captured by these. From the above the question arises whether there exists at the Caucasus serpentinites which are younger than pre-Middle Carboniferous, i. e. in particular Upper Carboniferous or Permian.

It seems to the author that from the data available the answer to this question should be rather a negative one. In the Permian conglomerates findings of serpentinite pebbles are known, but these are isolated instances (the Kumbizh gully). An analogous finding was mentioned to the author by L. F. Bochkarev and P. S. Samodurov. We may be sure, therefore, that at a thorough search in places where the serpentinites are overlain by the Permian, considerable quantities of pebbles will be found.

All the above is evidence against the presence of Permian serpentinites. This is fully consistent with the presence of platinoids in the conglomerates of the Permian red beds. On the other hand, the fact should be noted which has been established by the author's former observations along the left bank of the Bolshaya Laba River, down-stream of the mouth of the Zakan River.

A study of the correlation of the reddish-grey conglomerates occurring here, which were referred formerly by V. N. Robinson to the Upper Carboniferous and now to the Permian, and the serpentinite massif points to the presence of an tectonic contact. At the same time we should point to the presence of Mesozoic («neo-intrusive») serpentinites (Aibga, Kliat-kom, etc.).

A detailed study of the correlation between the Caucasian serpentinite massifs and the enclosing beds permits of the following conclusions to be made. In all cases when the enclosing metamorphic and sedimentary rocks are broken through by the enclosed serpentinites, interesting formations are observed at the contact, which may not without reason be called s e r p e n t i n e-q u a r t z-c a r b o n a t e r o c k s. They may be traced with the utmost clearness in relatively small massifs, giving the impression of a peculiar «reactional rims» formed at the periphery of the serpentinites. The presence of such formations at the southern contact of the Beden serpentinite massif with metamorphic schists made us assume the presence of an eruptive contact, which is contrary to the former conception of a tectonic contact. Therefore, we connect the origin of the nickel sulphide (niccolite, arite) mineralization with the serpentinite intrusion and by no means with the quartz diorites.

This has been proved by a study of many serpentinite massifs. At the same time it has been established that the serpentine-quartz-carbonate rocks («listwänites») arise in the apical parts of serpentinite massives i n d e p e n d e n t l y o f t h e c o m p o s i t i o n o f t h e e n c l o s i n g r o c k s (metamorphic schists, sandstones, shales, limestones, conglomerates). Thus, according to the author's observations, at the Caucasus the formation of the given rocks depends on the processes taking place during the ultrabasite intrusion, and their appearance at the contact with limestones (Kefar-Agur, Zaguedan) is an exception of the general rule.

While tracing the alteration of the mineralogical composition of these rocks, from the enclosing rocks to the serpentinites a quantitative increase of antigorite becomes obvious. This suggests that the above rocks are products of alteration of the hyperbasites themselves under the influence of hydrothermal carbonate solution enriched with CaO.

In conclusion it is of interest to note that in the closest proximity of certain serpentinite massifs there occur intrusions of different gabbro-diorites, diorites, syenite-diorites (Kefar, Kefar-Agur, Malyi Kefar, Azgara), diorites (Zaguedan and oth.), syenites (Bolshoy Zelenchuk, Ehresku, Guidam-Achkhishtara-bashi, Zakan, etc.); these seem occasionally to wrap the serpentinites. A detailed study of the contact zones between this rock complex and the serpentinites makes us assume a younger age of the former, which has already been pointed out by the author. Not only vein derivatives of the above rocks, breaking through the serpentinites, have been observed here, but also a regular enrichment of the above rocks with serpentinites, amphiboles, phlogopites, biotites, etc. in thick near-contact zones.

Especially typical of these are the «amphibole bombs» found in considerable numbers along the Kefar, Zaguedan and other rivers. Therefore, the prevalent opinion as to the gabbro-diorites, diorites and syenite-diorites being broken through by the serpentinite intrusions is to be revised. It should be pointed out that the localization of serpentinites and different gabbro-diorites, diorites, gabbro-syenites, syenites, etc. may be explained, on the one hand, by the similarity of the enclosing tectonical structure, and on the other, by their genetical relation. They are considered by the author as derivatives of one and the same original magma, being the products of its differentiation and characterizing a peculiar type of Caucasian province. The

same regularity may be described for rocks of a more acid composition, those of the quartz-diorite type contacting with serpentinites. The correlations of these rocks studied in a new area (the Bolshoy Blyb River system) point undoubtedly to a younger age of the acid rocks with regard to the hyperbasites. It is just this late influence of the hydrotherms of the acid intrusion which produced the talkites in the area of the Bolshoy and Malyi Blyb and Markopidge rivers. The area of distribution and occasionally considerable thickness combined with a satisfactory quality of the raw material point to the economic importance of these deposits. The area of the Blyb rivers is one of the easternmost outcrops of the band of talkite and serpentine-chlorite-talc deposits described previously within the Urushten-Armovka-Tryu River system. All the deposits have not only a common geological mode of occurrence, but also similar genetical relations, being the products of alterations of serpentinites under the influence of hydrotherms of acid intrusions.

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GENETICS

BREED, AGE AND SEX VARIATIONS IN BLOOD VALUE OF RABBITS

By Kh. B. ALPEROVICH

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Most of the researches on blood value of rabbits and rats deal chiefly with changes in blood value due to age. According to Kunde and others (4), newborn rabbits show the highest haemoglobin value which rapidly drops in the course of the first three days. Thereafter the drop in the haemoglobin value continues at a slower rate, until the rabbit is three weeks of age. The number of erythrocytes in the newborn is not large (from 4.5 to 5 millions). It likewise drops in the first days after birth reaching its minimum at the age of two weeks, after which it gradually increases, reaching the figure of 7 millions at the age of 16 or 18 weeks. Twelve hours after birth the diameter of the erythrocytes in rabbits equals on the average 10 μ and at the age of five or six months, 8.5 μ.

Similar data are given by Williamson and Ets (7) who show that the haemoglobin value in rats is fairly high in the first days after birth, but thereafter it steadily diminishes, until the animal is 50 days old; then the haemoglobin value rises once more.

Comparing the blood of newborn rabbits with that of their mothers and mature rabbits, Drastich and Santavy (1) came to the conclusion that newborn rabbits have a greater haemoglobin content (14.1 g) than mature rabbits (13.3 g). This they ascribe to the immaturity of the erythrocytes in newborn rabbits. Smith (6) brings interesting data concerning age variation in the diameter of the erythrocytes in rats, from the embryonic stage to maturity. According to these data, the average value of the diameter of the erythrocytes and the range of fluctuation of the mean steadily diminish from the early stages of embryonic development until they reach their lowest mark in the adult animal. Similar conclusions are arrived at also by Enzmann (2). As to the number of erythrocytes, Enzmann found them to be 0.69 million in the early embryos, as compared with 10 millions in the adult animal.

As regards the effect of sex dimorphism on the blood picture of rats and rabbits, the following literary data are available. Fritsch (3) has established that the haemoglobin content in rabbits equals 12.1 g for males and 11.6 g for females. The same picture is to be observed in regard to the number of erythrocytes, which equals 5.94 millions in males and 5.78 in females. Lange (5), in his studies of wild and domestic rabbits as well as rats, has likewise found a rather sharply pronounced sexual dimorphism as to the number of erythrocytes and haemoglobin content in the wild rabbit, both values being

greater in the male; the diameter of the erythrocytes proved, however, somewhat greater in the female. The difference between the blood value in the males and females of the house rat was considerably less than that of the wild rat.

We have investigated some of the rabbits in the vivarium of the Institute of Genetics of the Academy of Sciences of the USSR. We have investigated a total of 351 rabbits, male and female, including 127 of the Ermine breed, 55 of the Flandre breed, 44 of the White Giant breed, 64 of F_1 (Ermine × Flandre), and 61 of F_1 (Ermine × White Giant). All the rabbits were kept under similar conditions and given the same food. The examination was done in three periods: in March 1937, in June and in December 1938. Blood was taken from the ear between 10 and 11 a. m. Haemoglobin was determined by the Sahli method, the number of erythrocytes with the help of Thoma Zeiss' camera, and the size of the erythrocytes by dry undyed smears.

The Flandre and White Giant are the largest breeds and the Ermine the smallest. The mongrels, F_1 (Ermine × Flandre) and F_1 (Ermine × × White Giant) hold an intermediate position between the parental forms. The variations in the blood value of the rabbits, at different times of the year proved slight. For this reason the results have been summarized in Table 1.

Table 1

Breed	Haemoglobin (by Sahli)	Number of erythrocytes
Ermine	24.5	19.3
Flandre	20.3	32.3
White Giant	32.2	18.2
F_1 (Ermine × Flandre)	6.5	2.6
F_1 (Ermine × White Giant)	1.2	11.7

A) Age Variations. Our investigation comprised the following age groups: one day, three days, two, three, six and ten months. Table 2 shows that newborn rabbits display the highest haemoglobin value, but as they grow this value is gradually being reduced. Upon attaining two months the haemoglobin content begins to rise, reaching 76.34% in males at the age of six months. This haemoglobin value is with slight fluctuations retained by the animal at maturity. Both the diameter of the erythrocytes as well as the haemoglobin value in the first days after birth are at their maximum. The diameter of the erythrocytes in rabbits one day after birth is 7.89 μ, three days after birth—8.15 μ, two months—6.63 μ, and when mature—6.56 μ.

From the age of two months and until maturing the size of the erythrocytes remains unchanged. During the first days after birth the number of the erythrocytes, unlike the haemoglobin content and the diameter of the erythrocytes, is rather small. The number of erythrocytes in Ermine during the first day after birth is only 4.22 millions, while the haemoglobin content equals 10.78 g, or one million erythrocytes to 2.5 g of haemoglobin. With age the number of the erythrocytes increases reaching 6.38 millions in adult males, while the haemoglobin content equals 12.96 g, or nearly 2 g haemoglobin to every million of erythrocytes.

B) Sexual Dimorphism. In Table 2 the variations in the number of erythrocytes and haemoglobin content due to sex are expressed in terms of the excess of the blood value of the males, in per cent.

Table 2

Breed, Age and Sex Variations in Blood Value of Rabbits

Breed, age and sex	n	Haemoglobin $M \pm m$	Number of erythrocytes $M \pm m$	Size of erythrocytes $M \pm m_{\Sigma}$
Ermine				
1 day old	5	62.31±1.17	4.22±0.233	7.89 ±0.089
3 days old	1	73.65	5.56	8.15 ±0.072
2 months old male	14	59.43±1.42	6.04±0.179	6.63 ±0.069
female	7	63.4 ±1.31	5.94±0.307	6.72 ±0.071
3 months old male	2	69.99	7.11	6.50 ±0.047
female	2	65.18	6.00	6.45 ±0.040
6 months old male	27	76.34±0.96	7.01±0.183	6.52 ±0.0608
female	30	69.0 ±1.11	6.39±0.171	6.346±0.0608
10 months old male	7	69.27±2.26	6.15±0.350	6.51 ±0.165
female	7	63.05±2.87	6.24±0.428	6.37 ±0.085
Mature male	14	74.96±1.15	6.38±0.10	6.56 ±0.062
female	11	60.20±1.94	5.35±0.246	6.62 ±0.084
Flandre				
2 months old male	16	65.2 ±0.755	6.17±0.235	6.71 ±0.057
female	14	66.32±0.927	5.85±0.145	6.75 ±0.057
6 months old male	11	66.1 ±1.25	5.32±0.083	6.63 ±0.106
female	2	70.5	6.10	6.86 ±0.048
Mature male	3	77.5	6.15	6.60 ±0.052
female	9	63.56±1.76	4.63±0.325	7.0 ±0.108
White Giant				
2 months old male	13	64.08±1.69	6.11±0.125	6.66 ±0.069
female	6	65.9 ±2.43	6.73±0.231	6.68 ±0.071
3 months old male	9	63.25±2.22	5.84±0.203	6.56 ±0.089
female	1	56.87	5.09	6.70 ±0.037
6 months old male	4	66.57	6.17	6.73 ±0.052
Mature male	2	83.0	5.91	6.60 ±0.053
female	9	62.78±2.86	5.0 ±0.239	6.80 ±0.092
F_I (Ermine × Flandre)				
2 months old male	16	65.07±1.02	5.71±0.141	6.67 ±0.062
female	14	64.8 ±1.19	5.74±0.233	6.73 ±0.056
6 months old male	10	69.15±1.32	6.65±0.160	6.62 ±0.085
female	4	68.7	5.87	6.65 ±0.054
Mature male	9	76.75±1.99	6.52±0.243	6.61 ±0.055
female	11	72±1.05	6.35±0.130	6.53 ±0.053
F_I (Ermine × White Giant)				
2 months old male	12	61.33±1.83	5.57±0.205	6.56 ±0.073
female	5	55±3.61	5.57±0.431	6.75 ±0.049
3 months old male	3	62.6	4.93	6.95 ±0.051
6 months old male	19	72.96±1.44	6.24±0.162	6.54 ±0.054
female	13	66.77±0.986	5.64±0.120	6.51 ±0.056
Mature male	7	71.1 ±1.625	5.91±0.206	6.70 ±0.063
female	2	71.9	5.29	6.70 ±0.057

The number of red corpuscles in the blood of the males is considerably higher than that of the females. The size of the erythrocytes is, however, somewhat larger in the females. Thus, we may conclude that the blood of the males possesses a greater oxidizing capacity than the blood of the females. This conclusion is also confirmed by the data obtained by Lange ([5]) in his experiments on wild rabbits.

C) Breed Variations. A comparison made between the blood variations in mature rabbits shows that the bigger breeds (Flandre and White Giant) have a somewhat higher haemoglobin value and greater size of the erythrocytes, but a smaller number of erythrocytes. Male mongrels occupy an intermediate position between the parental breeds. Adult female mongrels show a higher haemoglobin value and greater number of erythrocytes than their full-blooded parent females (Table 2).

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GENETICS

NUMERICAL RELATIONS OF SEXES IN VARIOUS HYBRID COMBINATIONS IN HOP

By I. N. HOLUBINSKY

(Communicated by N. I. Vavilov, Member of the Academy, 11. VIII. 1939)

Hop (*Humulus Lupulus* L.) belongs to plants which display no Mendelian 1 : 1 sex ratio when propagated by seeds: the proportion of male plants in hop is always considerably smaller than the theoretically expected 50% ([3-8,10,11,12,15]). Besides, there is a rather characteristic unstability in the proportion of the male and female plants in different years as reported by different investigators ([6,7,8,15]). Correns, in his works on the inheritance of sex-ratio in higher plants ([7,8]), reports that the proportion of male individuals in hop is from 9.8 to 22.3%. Besides, following this writer, hop is the only plant species with such a great variation of this ratio. This circumstance alone should have directed the attention of investigators toward a further study of the phenomenon in question and toward the search for its causes. Whether it is the influence of external conditions (climatic, edaphic, or others) which were pointed out by a number of authors in respect to Japanese hop (*Humulus japonicus* Sieb. et Zucc.) ([1,2,6,7,8,9,13,14,15]), or the variation in the sex ratio should be explained by the inner factors of individual plants; the question arises to what extent this character is a hereditary one ([2,3,5,6,9,10,12]).

In the work on hybridization our attention was directed both toward the considerably lowered proportion of male individuals in hop and on the variation in this ratio. In the course of analysis of the phenomenon in question we have found that different hybrid combinations in the same year and under identical conditions of cultivation produce male plants in different proportions, the latter varying from zero to 32.6%. When crosses were conducted following the diallel-type, we have noticed that the same maternal form produced different proportion of male offspring when crossed with different parental individuals (Table 1).

Crosses were made in 1933. For the experiment in question were selected two female plants which proved to be the best among local population at the commercial plantations of this station; they were found to be the best both with respect to resin-content and to productivity. These plants were crossed with a number of male plants which were similarly found to possess an increased resin-content. Aside from them there was taken one female plant of the variety Serebrianka which was pollinated with a mixture of pollen of the male plants noted above. The seeds obtained were sown in 1934 into hotbeds and the young seedlings were transferred in the same summer to a nursery for hybrids; they remained there until fructification. All

the combinations were sown out and planted into the open at the same time and under absolutely identical conditions with respect to soil, moisture, illumination, etc. In 1935, i. e. on the second life's year, the absolute majority of the seedlings displayed sex, and the plants of the one and the other sex were recorded at the end of the same summer. The results are summarized in Table 1.

Table 1

Quantitative Relation of Sexes in Hop in Different Hybrid Combinations

Combination *	Number of offspring obtained	Sex relations							
		Female		Male		Hermaphr.		No sex displ.	
		No.	%	No.	%	No.	%	No.	%
872 2/4 × 12/15	48	44	91.7	1	2.1	—	—	3	6.2
872 2/4 × 15/13	39	38	97.4	—	—	—	—	1	2.6
872 2/4 × 12 28	3	3	100	—	—	—	—	—	—
872 2/4 × 2/13	17	14	82.5	—	—	1	5.9	2	11.8
872 2/4 × 7/23	15	14	93.3	—	—	—	—	1	6.7
872 2/4 × 16/6	11	11	100	—	—	—	—	—	—
872 2/4 × 19 28	22	19	86.4	1	4.5	—	—	2	9.1
872 2/4 × 18/24	44	41	93.2	—	—	1	2.3	2	4.5
Sum/Mean	199	184	92.5	2	1.0	2	1.0	11	5.5
823 2/8 × 12/15	170	138	81.2	14	8.2	—	—	18	10.6
823 2 8 × 19 28	90	80	88.9	6	6.7	—	—	4	4.4
823 2 8 × 16/6	79	67	84.8	6	7.6	—	—	6	7.6
823 2 8 × 15/41	93	88	94.6	3	3.2	—	—	2	2.2
823 2/8 × 10/2	82	69	84.1	9	10.9	—	—	4	5.0
Sum/Mean	514	442	85.9	38	7.4	—	—	34	6.7
Serebrianka 6/12 × mixed pollen	770	564	73.2	184	23.9	—	—	22	2.9
Total number of plants according to combination	1 483	1 190	80.2	224	15.1	2	0.1	67	4.5

The results obtained made us repeat the analysis of sexes in the crosses of subsequent years. Such an analysis was conducted in 1937 on seedlings in the second year of their life (sown in 1936, seeds of the 1935 cross).

For pollination was chosen a single plant with yellow leaves found as a natural bud mutation at the hop-plantation of the neighbouring collective farm, and one plant of the ordinary hop from the commercial mixture of varieties. Pollination was done with a mixture of pollen of the male plants. Aside from this, one shoot of the yellow leafy plant was left without isolation or artificial pollination; a small amount of seeds were collected from it and planted in order to determine the proportion of male plants from open pollination. As in 1933, sowing and planting of the seedlings were conducted under identical conditions side by side with the seedlings planted in 1934.

* The figures contained in the column «Combination» denote: the first one, number of the plot, the second—the row (numerator) and plant (denominator).

The results of the analysis of the sex ratios in the 1935 crosses are given in Table 2.

Table 2

Quantitative Relations of Sexes in Hop in 1935 Crosses

Combination	Number of offspring obtained	Sex relations							
		Female		Male		Hermaphr.		No sex displ.	
		No.	%	No.	%	No.	%	No.	%
Yellow-foliate plant pollinated with mixture of pollen	366	276	75.4	64	17.5	1	0.3	9	6.8
Yellow-foliate plant open pollinated	2	2	100	—	—	—	—	—	—
893 6/5×mixture of pollen	1	1	100	—	—	—	—	—	—
Sum/Mean	369	279	75.6	64	17.5	1	0.3	9	6.8

It was also of interest to clear up the question on the sex ratio in hop when different sexual types were intercrossed. The existing literary data ([2,3,5,6,10,12]) speak for a variation of this ratio in connexion with the degree of expression of the one or the other sex in the maternal forms, which is wholly explicable on the basis of Mendelian segregation. We have decided to check this point on the monoecious hop plants (of the eumonoikist type, following Correns' terminology) which are grown at a special nursery at this station. These monoecious plants are characterized by an entirely normal development of the female flowers and female gamethophytes, and by a degeneration at a certain stage of the male gametophyte; the flower buds have quite a normal appearance and sometimes develop into superficially normal male flowers ([16]). While the female flowers which develop an entirely normal embryo-sac are capable of fertilization and produce entirely viable seeds, the male flowers die at a definite stage of development and, as a rule, produce no normal functional pollen grains. Seeds of such monoecious plants were taken for the investigation of the character of inheritance of sex. No artificial pollination was done, as it was difficult to ensure isolation, for these plants were growing among male individuals of hop, and it was extremely difficult to guard them against undesirable foreign pollen. Sowing of seeds and care for them, as well as the subsequent way of cultivation of seedlings differed in nothing from those in the rest of crosses (Tables 1 and 2). The results of the analysis are presented in Table 3.

In examining the above tables, we notice in the first place the absence of the theoretically expected Mendelian 1 : 1 sex ratio, both in individual crosses and in the sum total, in all of the crosses of the two years, despite the very great total number of plants (out of the 1898 plants there were 296 male ones, or 15.1%). Besides, there are great variations in the percentage of male plants in different combinations. Individual parental forms definitely tend to segregate out a minimum proportion of male plants. The percentage of the latter obviously depends both on the maternal and paternal individuals, but the former should be supposed to play the decisive rôle. Thus, for example, the maternal plant 872 2/4 (Table 1) produced no male offspring with the majority of paternal forms and only in two cases it gave one male plant in each of them. On the contrary, the other maternal plant (823 2/8) gave male progeny withe ach of the paternal forms (partly the same ones as

Table 3

Quantitative Relations of Sexes in the Offspring from Seeds of Monoecious Plants

Maternal forms	Number of offspring obtained	Sex relations							
		Female		Male		Hermaphr.		No sex displ.	
		No.	%	No.	%	No.	%	No.	%
Nursery plant ♂ 2/7	16	11	68.8	4	25	—	—	1	6.2
» » ♂ 2/12 . . .	20	15	75.0	4	20	—	—	1	5.0
» » ♂ 2/13 . . .	10	10	100	—	—	—	—	—	—
Sum/Mean . . .	46	36	78.2	8	17.4	—	—	2	4.4

in the first instance). The increased percentage of male plants (17.3%) was also produced by the yellow-foliate form and two hermaphrodite plants (17.4%), whereas one of them produced again no male offspring at all.

The values obtained thus support our previous statement ([17]) that the increased percentage of female plants among seedlings of hop cannot be explained by parthenogenetic formation of a fraction of seeds as suggested by Wettstein ([18]). On the other hand, it is difficult to refer it to surrounding conditions, as argued by Schaffner ([13]).

During a short time we were inclined to adopt as a working hypothesis the assumption as to a lower viability of the male offspring; however, this hypothesis soon proved inconsistent in the course of further experimental study. In the first place, it refused to be brought in accord with the fact that the conditions of sowing and transplantation of the hybrid seedlings into the open were in 1936 somewhat worse than in 1934 and, consequently, the proportion of dying plants was greater. Nevertheless, the percentage of male individuals proved even somewhat higher than in 1934. On the other hand, special care given to diseased plants which were likely to die, has shown that the proportion of male plants among such individuals did not exceed that existing among normal plants. Finally, attempts were made to select seedlings for the coloration, spindle-shaped thickenings of the stem, etc., as well as sorting out seeds for size and colour. All these attempts were unsuccessful, since no noticeable modification in the sex ratio could be obtained.

The reason for the different proportion of the male and female individuals in hop should be thus sought for, it seems to us, in the inner peculiarities of the parental individuals. Only in this manner one can expect to explain the unequal sex ratio in the various combinations in *Humulus Lupulus* which sometimes goes as far as to a full absence of male individuals ([7,8]). Further experiments should be directed toward the search for these internal causes.

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GENETICS

PRODUCTION OF AN AUTOHEXAPLOID *SOLANUM VALLIS MEIXCI* JUZ. BY MEANS OF ITS CULTIVATION AT THE PAMIR

By R. L. PERLOVA

(Communicated by N. I. Vavilov, Member of the Academy, 21. VIII. 1939)

It was proved by numerous experiments of various investigators that autopolyploids arise in plants under external influences. It is produced artificially through influencing of somatic or sex-cells by decapitation, by high or low temperatures, by treatment with colchicine, acenaphthene, X-rays, etc.

There are also rather abundant literary data on production of autopolyploids in nature by the action of low or high temperatures, and it is indicated that their areas are confined to alpine localities or to regions of high northern latitude and to the equatorial zone. We shall cite in this paper only a few of them.

Hagerup has shown that the area of the tetraploid *Empetrum hermaphroditum* ($n=26$) lies between 60 and 79° n. l., whereas the northern limit of the diploid *E. nigrum* ($n=13$) is at 63°. South of 60° *E. hermaphroditum* is found only in mountains of France and Switzerland at an altitude of 2300 m above the sea level (2). An analogous situation was shown by Hagerup to exist in the various genera of *Bicornes*, the tetraploid species of each genus possessing a more northern area than the diploid ones (3).

It has been established that polyploidy depends in Sahara on high temperature and dry climate. It is especially pronounced in the genus *Eragrostis*; the polyploid species of this genus ($n=20$ and especially $n=40$) grow on poor sandy dunes and prove to be more hardy and drought-resistant as compared with the diploid species ($n=10$) (4).

Following Manton, the area of tetraploid varieties of *Biscutella laevigata* is confined to alpine regions of Southern Europe and reaches an altitude of 3300 m above the sea level, whereas the diploid forms are distributed in the valleys of the rivers Rhine, Elbe and Danube (5). The tetraploid strain of *Nasturtium officinale* ($2n=64$) is confined to the northern part of the area of the genus *Nasturtium*, the diploid strain ($2n=36$) being wider distributed (6).

Strelkova indicates that the areas of the polyploid series of the genus *Alopecurus* are confined to alpine regions of Crimea, Caucasus, Middle Asia (the series *Vaginatae*, $2n=56$) or to the Arctic zone of Europe, Asia and North America (series *Alpinae*, $2n=\pm 98-105$) (9). Sokolovskaja and Strelkova who have studied cytologically various species of *Gramineae* collected by them at Pamir and Altai have demonstrated that 85% of the Pamir species and 65% of the Altai species are polyploid (8).

Tischler who studied statistically polyploid species in Schleswig-Holstein where climatic conditions were unfavourable dur ng the glacial period, has found that 44.1% of the species belonging to this province were polyploid, and, besides, that polyploids are more abundant in the northern regions than in southern ones ([10]). Rohweder and Wulff have established that soil conditions play a rôle in production of polyploid forms in Schleswig-Holstein ([7],[11]).

All the writers mentioned above support the hypothesis that extreme living conditions (climatic, thermal and soil conditions) characteristic of arctic, alpine and desert regions often effect in diploid species disturbances of reduction division which lead to production of autopolyploids. Our work, as will be shown below, produced an experimental proof of the correctness of this hypothesis.

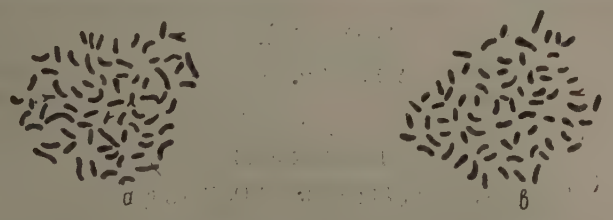
Solanum Vallis Mexici Juz. is an alpine wild Mexican species of potato from the state of Distrito Federal. It has been found at the extinct volcano Malinale, at an altitude of 3250 m above the sea level, on a glade in a pine wood growing on sand. It is taxonomically related to the *Longipedicellata* group; a triploid ($2n=36$). According to Bukassov's hypothesis, *S. Vallis Mexici* is of hybrid origin, probably being a hybrid between the diploid *S. verrucosum* ($2n=24$) of the *Demissa* group and some tetraploid species closely related to *S. Antipoviczii* ($2n=48$) of the *Longipedicellata* group ([1]).

S. Vallis Mexici is of interest for plant-breeding purposes as it possesses wide ecological plasticity, is more drought-resistant and less apt to the degeneration diseases than other potato species; it is, besides, phytophtora-resistant. However, owing to triploids, it is sterile. Numerous attempts made during several years to obtain seeds from natural or artificial self-pollination or from various crosses with di-, tri-, tetra-, penta- and hexaploids at the agricultural experiment station «Krasny Pakhar» of the All-Union Institute of Plant Industry gave no results. Only in 1937 V. I. Nesterovich, who pollinated with greatest care 978 flowers by 26 different species, obtained for the first time in 5 combinations one berry in each, containing one seed per berry. Two of them proved to be viable, namely: *S. Vallis Mexici* × *S. tuberosum* v. *multibaccatum* and *S. Vallis Mexici* × *S. andigenum*. According to the cytological studies by V. I. Ivanov, these hybrids were pentaploid ($2n=60$) and should have arisen from a fusion of non-reduced gametes of *S. Vallis Mexici* (i. e. containing the somatic number 36) with reduced 24-chromosome ones of the tetraploid.

In 1937 we have grown *S. Vallis Mexici* together with many other species of the South-American potato under the conditions of the alpine desert of Pamir near the town Khorog at an altitude of 2320 m above the sea level. The climate of Khorog is dry, sharply continental; it is characterized by an absence of rains during the summer months, by extreme temperature fluctuations, especially at the surface of the soil (up to 40—50°), low relative humidity of the air which amounts on the average to 30—40% and drops on some days to 15—20%, especially during the day hours. *S. Vallis Mexici* at Pamir proved to be very drought-resistant, very frost-resistant, formed tubers under natural field conditions (at Leningrad where day is longer, it did not produce tubers) and, which is of greatest interest to us, it proved to be fertile. The production of berries was observed in September, especially toward the end of this month, and at the beginning of October, i. e. coincided with an abrupt drop in the mean day and night temperature to 12—15°, the minimum temperature on the surface of the soil being as low as 0° and, on some days, even below (—2, —3°). Owing to late season, the majority of the berries and especially of the seeds could not mature toward the time of harvest (25—30 of October), so that we were able to collect only 15 seeds suitable to sowing. These seeds were sown in 1938 in the greenhouse at the experiment station «Krasny Pa-

khar», and the 9 seedlings obtained from them were further cultivated in hotbeds. Chromosome count made by P. M. Mamulashvili has shown that all the 9 seedlings were hexaploid, i. e., possessed a double chromosome number as compared with the triploid *C. Vallis Mexici*; the chromosome number varies from 70 to 73 (Figs. *a* and *b*). It appears to be probable that low night temperatures had disturbed reduction division which, following to observations by Sokolovskaja and Strelkova, occurs in potato at Khorog exclusively at night (from midnight to 3 a. m.); the gametes with somatic numbers 35, 36 or 37 were thus formed and have fused together.

Comparison of the hexaploid seedlings with the triploid species did not show any qualitative differences in morphology; there were, however, quantitative differences: in hexaploids the leaf coloration and the colour of the corolla were more intense, the leaves were less dissected and denser pubescent.



the sections of the leaves were somewhat larger, the diameter of the corolla and the proportion of fertile pollen were greater (see table).

It should be especially noted that the hexaploid is readily crossed with *S. tuberosum*, a cultivated variety *Stärkeragis* ($2n=48$). From the 67 pollinated flower buds were obtained 15 berries, i. e. 22.4% of pollinations were successful. There were on the average 18—20 seeds per berry and the seeds germinated well. From 287 seeds there were obtained 242 plants, i. e. 84.3%.

On the basis of these, although preliminary, data we consider our seedlings obtained from seeds produced by self-pollination under the conditions of Pamir to be a cytological hexaploid strain of the triploid species *S. Vallis Mexici*. There is no doubt that further and more detailed study will discover new and substantial characters which, if constant, will furnish grounds for promoting the cytological race to a taxonomic unit, i. e. a variety or form.

Comparison of the Quantitative Characters in the Triploid and Hexaploid *S. Vallis Mexici*

S. Vallis Mexici	Size of the first pair of sections of the 6th leaf downwards from the inflorescence (average in cm)			Diameter of the corolla in cm	% of fertile pollen	% of giant pollen grains
	length	width	index			
Triploid	4.3	1.7	2.5	3.0	6—15	2.2
Hexaploid	4.8	2.4	2.0	3.4	68—93.5	97.8

Autopolyploids have been noted in wild species of potato by Bukassov. He considers the Uruguai species *S. Commersoni* and the Argentine species *S. Millanii* to be autotriploids, as only diploids are known to occur within

the area of these species and in neighbouring regions, the tetraploid species lacking and no indications of their hybrid origin being available. The Mexican hexaploid *S. demissum*, according to Bukassov, is a product of chromosome doubling in the triploid *S. Vallis Mexici* or some similar species, as tetraploids are lacking in the *Demissa* group. However, our hexaploid strain of *S. Vallis Mexici* has nothing in common with *S. demissum*; its parental species should be, therefore, some Mexican triploid which remains as yet unknown to us.

The instance of the conversion of the triploid *S. Vallis Mexici* into a hexaploid, first, proves the correctness of the hypothesis advanced by many writers, i. e. on the effect of the alpine conditions upon the chromosome doubling in adventive species, thus leading to autopolyploids; secondly, we are pointing out the possibility that the alpine conditions of Pamir may influence the secondary evolution or the origin of forms within a species. Our work is the first attempt in this direction.

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GENETICS

TYPES OF GAMETES PRODUCED BY STRUCTURAL ABERRANTS IN *CREPIS CAPILLARIS* WALLR.

By D. N. ARENKOVA

(Communicated by N. I. Vavilov, Member of the Academy, 26. VII. 1939)

The available literary data on the gametes formed by structural aberrants rest mainly upon the hypothesis on the unviability of unbalanced genomes and upon determination of the proportion of normal pollen. Thus, sterility amounting to 50% in plants heterozygous for the translocation between two non-homologous chromosomes is explained simply through formation of 50% of gametes possessing some chromosome regions in excess and deficient in others, in accord with the simplest scheme of chromosome assortment at meiosis ([1],[2]). 75% sterility is explained in the same manner in the case of two independent translocations ([1]). Although the empirical data agree with the theoretical expectation, it is desirable nevertheless to obtain a concrete answer to the question in the form of a direct study of the karyotypes of the sex elements.

As a material for the present investigation served X-ray-translocants of *Crepis capillaris* ([4]) which were kindly turned over to me by Prof. G. A. Levitsky, to whom I wish to express my deep gratitude. First divisions in the pollen grains were studied with the aid of the aceto-carmin method.

Altogether one normal plant and 6 aberrants were studied.

I. The normal karyotype consists of 3 chromosome pairs which are designated A, C and D. Their dimensions ([3]) are as follows: $A=6.1 \pm 1.9$ μ, $C=3.5 \pm 0.8$ μ, $D=6.5 \pm 0.2$ μ. Fifty division figures were examined in the normal form of *C. capillaris*. It produced only one type of pollen grains: A, C, D (Fig. 1). There was no pollen sterility.

II. Homozygous translocation «from $2D$ to $2A$». In the somatic set there were present two pairs of similarly modified chromosomes: $2(A+d)$, $2(D-d)$. Fifty division figures were studied. One type of pollen grains was found: $A+d$, $D-d$, C (Fig. 2). There was no pollen sterility.

III. Heterozygous inversion «$A-A_i$»* (Fig. 3). It was expressed in a modified ratio of the arms of the A-chromosome, from the normal 3 : 1 to 1 : 1, whereas its total length remained unchanged. In the somatic set there was only one modified A-chromosome. Fourty-four division figures were studied. Three types of pollen grains were formed: 1) normal A, C, D (Fig. 1)**—

* This modification designated at first as «translocation of the fiber attachment» represents an internal inversion comprising the attachment (Korukaev, unpublished).

** Lack of space makes it impossible to describe all of the karyotypes found in pollen grains of each of the aberrants; we will refer, therefore, to the analogous chromosome sets found in other aberrants. For the same reason we have not represented somatic plates of the aberrant forms, but instead diploid sets of the pollen grains are given.

50%; 2) «A_2», C, D (Fig. 4)—48%; 3) diploid pollen grains—2% (Fig. 3). Pollen sterility—10%.

IV. Heterozygous «inversion» D (Fig. 5). There was one modified D-chromosome in the somatic set. There were studied 96 division figures. Four types of pollen grains were found: 1) Normal (Fig. 1) A, C, D—51%. 2) Inverted D-chromosomes, A and C (Fig. 6)—44.1%. 3) Four chromosomes: A, C, D plus a fourth one resembling the proximal end of the D-chromosome without a satellite (Fig. 7). It was found in 2.1% of cases. The distal portion of the D-chromosome was torn off and the satellite has gone with A. The thread is evidently the less resistant part and breaks(4), so that the two resulting fragments of the D-chromosome are distributed at random. We have not observed the corresponding type which should have been expected from the meiotic behaviour, viz., the one consisting of A, C and the distal fragment of D without a kinetic constriction. 4) Diploid pollen grains —2% (Fig. 5). Pollen sterility—20%.

Fig. 1—20.

V. «Heterozygous» translocation «from D to A» (Fig. 8). There were two modified chromosomes in the somatic set, viz., $A+d$ and $D-d$. Altogether 261 division figures were studied. Six types of pollen grains were found: 1) Normal set: A, C, D (Fig. 1)—44%. 2) Balanced set: $A+d$, $D-d$ and C (Fig. 2)—27.8%. 3) Duplication: D, C and $A+d$ (addition of the distal segment of the D-chromosome) (Fig. 9)—20%. The deficient type lacking the distal segment of D which should result from meiosis was not observed. 4) Four chromosomes: D, C, $A+d$ and $D-d$. An extra D-chromosome is present in the set (Fig. 10). Found in 1.6% of cases. The types containing only the chromosomes A and C which were expected to arise simultaneously were not observed. 5) Four chromosomes: A, D, C and $D-d$; the fourth was the extra one (Fig. 11). Found in 5.6% of cases. The type arising at meiosis at the same time with it and consisting of $A+d$ and C was not observed. 6) Pollen grains with diploid sets—0.4% (Fig. 8). Pollen sterility—53%.

VI. «Heterozygous» translocation «from D to A» with modified ratio of arms in A (A_1) (Fig. 12) had in the somatic set 3 modified chromosomes: $A+d$, A_1 and $D-d$. Seventy-two division figures were studied. Seven types of pollen grains were found. No fully normal haploid set A, C, D should be theoretically expected in this form; as a matter of fact it was not found.

1) The «normal» type of pollen grains is the one containing A_i, D and C (Fig. 4). It was observed in 33.4% of cases. 2) The balanced one, $A+d$, $D-d$ and C (Fig. 2)—16.65%. 3) Containing duplication $+d$ and consisting of $A+d$, D and C (Fig. 9)—5.55%. 4) The type corresponding to the foregoing one and deficient on material, i. e. A_i, $D-d$ and C; it was observed in 20.8% of cases (Fig. 13). 5) This type contained A , D, C and a proximal segment $D-d$. The latter was the extra-element (Fig. 14). It was found in 20.8% of cases. The karyotype which should have arisen in meiosis, i. e. the one consisting of two chromosomes C and $A+d$, was not observed. 6) Four chromosomes: $A+d$, $D-d$, D and C (Fig. 10). A whole D-chromosome was in excess. Found in 1.4% of cases. No corresponding type which should have arisen at meiosis, i. e. the one lacking the D-chromosome and consisting of two chromosomes A_i and C, was observed. 7) Diploid pollen grains in 1.4% of cases (Fig. 12). Pollen sterility—75%.

VII. «Heterozygous» translocation «from A to C» (Fig. 15). Two modified chromosomes were present in the somatic set: $A-a$ and $C+a$. Eighty-two division figures were studied. Nine types of pollen grains were found: 1) The normal one A, C, D (Fig. 1)—45.1%. 2) The balanced one: $A-a$, $C+a$ and D (Fig. 16)—17%. 3) Containing duplication ($+a$): A, D and $C+a$ (Fig. 17)—3.7%. 4) The deficient one ($-a$): $A-a$, D and C (Fig. 18)—6.1%. 5) Consisting of 4 chromosomes: A, D, C and $A-a$. The latter was the extra one (Fig. 19)—5%. 6) Consisting of 4 chromosomes: A, D, $A-a$ and $C+a$. The A-chromosome was in excess (Fig. 20)—1.2%. 7) Consisting of four chromosomes: A, D, C and $C+a$. The latter was in excess (Fig. 21)—11%. 8) Two normal chromosomes D and C and two modified ones $A-a$ and $C+a$ (Fig. 22). The C-chromosome was the extra element—8.5%. At the same time with the 4 «excessive» sets which have been just described the following four «deficient» ones should have arisen at meiosis: a) D, $C+a$; b) D, C; c) D, $A-a$; d) A, D. However, they were never found by us. 9) Diploid pollen grains—2.4% (Fig. 15). Pollen sterility—53%.

The pollen in the normal form of *C. capillaris*, as well as that in the homozygous translocation «from $2D$ to $2A$», was uniform as to size and stained well and uniformly. In heterozygous translocants [1) «from D to A», 2) «from D to A» plus translocation of the kinetic constriction in A (A_i), and 3) «from A to C»], on the contrary, the pollen greatly varied in size, in shape and in number of pores. No correlation between the size of pollen grains and the total length of the chromosomes of the set could be established. Thus, four-chromosome sets were found in pollen grains which exceeded in size the normal ones and had from 4 to 6 pores (normal pollen grains have 3 pores). At the same time diploid or deficient sets were found in pollen grains which were normal with regard both to size and structure. In determinations of the percentage of sterile pollen only those pollen grains were classified as normal ones which were well stained and contained typically developed sperms.

At meiosis in the heterozygous translocants described above there were observed instead of ordinary bivalents groups of four formed by chromosomes involved into the translocation(5). Two types of chromosome disjunction may be effected in such groups: the alternating and the adjoining ones. As a result of the former pollen grains should be formed which contain either normal or balanced sets of 3 chromosomes. As a result of adjoining disjunction there arise pollen grains with duplications or deficiencies. Formation of the four-chromosome types of pollen grains is probably due to «non-disjunction» of the chromosomes which is favoured by the formation of groups of four at meiosis. This is supported by the fact that «non-disjunction» was never observed in normal individuals or in homozygous translocants «from $2D$ to $2A$». Frequencies of each of the pollen grain types show that frequency

of occurrence of certain types in many cases does not correspond to expectation; thus, for example, in the VII aberrant normal and balanced pollen grains should be formed in equal numbers; as a matter of fact, however, the former were found in 45.1% of cases, whereas the latter only in 17% of cases. A further example is the occurrence of pollen grains with 4-chromosome sets or the total absence of the 2-chromosome pollen grains. Such phenomena should be obviously explained through reduced viability of those chromosome sets which deviate from the norm and especially of the «defective» ones; owing to this, the corresponding pollen grains either die at the earliest stage of development, or are delayed at the very first division.

At any rate the majority of the karyotypes found by us may partake in fertilization. Aside from the normal and balanced ones, this is true of the 4-chromosome gametes possessing a whole extra chromosome (Figs. 10, 20, 22) forming full trisomics, inasmuch as all of them were actually obtained ([6]); it is probably similarly true of gametes with reduced extra chromosomes (Figs. 7, 11, 14, 19), and is not excluded in the case of gametes possessing an increased extra chromosome (Fig. 21), or in cases of deficiency of a section of the one of the chromosomes (Figs. 13, 18), which may be compensated by a gamete containing in excess the corresponding chromosome section. Karyotypes consisting of *A*, *C* and a distal fragment of the *D*-chromosome without a kinetic constriction should be classified as absolutely unviable. All the two-chromosome pollen grains probably die at earlier stages or are incapable of division (only the two following cases belonging here were actually found: $A+C$, C and $A+d,d$).

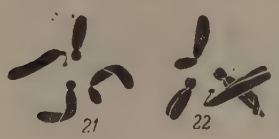

Fig. 21—22.

In comparing our data obtained from a study of *C. capillaris* with those belonging to other students ([1],[2]), one has to observe a strong divergence. The writers just cited thought, first, that in nearly all the cases studied four types of gametes were formed in the case of presence of a group of four chromosomes at diakinesis; secondly, that all the types of sex-cells are formed in equal numbers; third, that the chromosome number of the haploid set in pollen grains remains normal in all the cases; finally, that in all the cases the only fertile gametes are the normal or balanced ones, whereas those with deficiencies of duplications, as a rule, are aborted. It follows from our data that in heterozygous translocants of *C. capillaris*, the variety of directly observed karyotypes considerably exceeds that previously derived theoretically and cannot be brought into accord with the proportion of sterile pollen in definite aberrations.

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PLANT PHYSIOLOGY

EFFECT OF FERTILIZERS AND SPRAYING UNDER THE CONDITIONS OF INCREASED AIR HUMIDITY

By V. F. ALTERGOT, F. V. SHATILOV and G. N. KHUNZARIDZE

(Communicated by A. A. Richter, Member of the Academy, 26. VIII. 1939)

Unlike to those investigators who interpreted the death of plants exposed to critical temperatures as being due to coagulation of the plasm complex([7],[14]), one of the present authors succeeded in establishing that depression and death of the vegetative cell under the action of high temperature results from the disturbance of normal metabolism and self-poisoning of the cell by toxic products of decomposition ([1],[2]). Our conclusions have been supported by a number of works ([4],[5],[8],[9],[10],[11]). The authors, while discussing our data in more detail, arrive at the conclusion that the fatal effect of drought, low and high temperatures is connected with the disturbance of enzymatic equilibrium which is inherent in the normal cell, with its displacement towards an increase of the hydrolyzing and decrease of the synthesizing capability.

Our data ([1],[2]) have been evidenced, among others, by Rakitin and Shumova ([6]) in th ir investigation on the causes of potato degeneration when cultivated in the south. High temperatures lead to the accumulation in the potato tubers of toxic products of metabolism, of ethyl alcohol, acetaldehyde and ammonia. The above authors give an interpretation of the rôle of high temperatures in the phenomenon of southern degeneration of potato.

Departing from our previous data([2]), we made in the present investigation an attempt to find out a mode of «training» a heat-resisting vegetable organism. Three summer wheat varieties*: «Sarrubra» (v. *alborubrum*), «Marquis» and v. *erythrospermum* 0341, were grown in a greenhouse in vessels containing 9 kg of black-earth each at a constant humidity of 60% to the total moisture capacity. It seemed of particular interest to investigate the dependence of heat-resistance on the presence of different amounts of nitrogen in the soil. Taking conventionally 3.5 g per vessel as a normal nitrogen content in the soil (variant NPK), we introduced into experiment variants with an excess of nitrogen (10.5 g, variant NPK'), and without nitrogen (PK). Within each variety, the variants of fertilizers per vessel (correction being made for the active element) were the following:

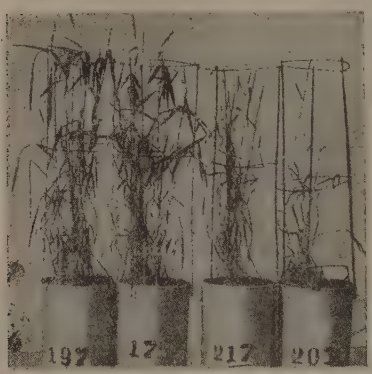
1. NPK'—montan-nitre—10.5 g; superphosphate 14.6 g; silvinite—3 g
2. NPK — » 3.5 » » » 14.6 » » 3 »
3. PK — » 0 » » » 14.6 » » 3 »
4. Control—without fertilizers.

* Seed material obtained from A. P. Shekhurdin.

Beginning with tillering, the plants of variants NPK and PK proved remarkable for their height, intense pigmentation, length and width of leaf blades. The plants of variants NPK' and those without fertilizers lagged behind in development and showed a reduced pigmentation.

Temperature treatment was applied in a glazed chamber of a 4 m^3 capacity, supplied with a heater. To avoid soil overheating, the vessels were placed into running water.

1. Effect of Spraying upon Ammonia Content in Leaves of Wheat Plants Treated with High Temperatures. Klein and Steiner([13]), as well as Pearsoll and Villemorin ([15]) have found that plants are able under normal conditions to give off through their leaves into the surrounding medium considerable amounts of products of nitrogen metabolism. In this connexion, our assumption as to the ammonia being washed out in the course of spraying, seems quite probable.



«Sarrubra» given PK: 197 and 175, under spraying; 217 and 203, without spraying (by the 12th day of experiments).

Experiment 1. «Marquis» and «Sarrubra», both at the phase of outset of stalking, are exposed during 4 hours to the action of temperatures from 40 to 42°C, the relative air humidity being 48—50% (for August). After thorough heating the plants were watered with a spray. Ammonia content in leaves was determined after Longi ([2]) previous to heating, after heating, and after the plants were washed during 10 min. with a spray and the leaves dried during 20—25 min. in the open air. The results are summarized in Table 1.

Table 1

Washing out of Ammonia from Leaves of Wheat by Means of Spraying

Material	Fertilizer	Amount of ammonia nitrogen in mg per 1 g of dry leaf mass		
		Before heating	After heating	After spraying
«Marquis»	NPK'	0.090	0.118	0.074
	NPK	0.102	0.122	0.051
	PK	0.108	0.112	0.057
	Without fert.	0.056	0.094	0.065
«Sarrubra»	NPK'	0.075	0.105	0.070
	NPK	0.107	0.129	0.091
	PK	0.083	0.223	0.052
	Without fert.	0.074	0.084	0.069

Basing on our former data ([2]), it may be assumed that in this case we have to do not with washing out, but rather with resynthesis taking place in the course of spraying and drying of leaves in the open air (35 min.).

Experiment 2. The plants are heated under the same conditions for 6 hours. Ammonia content in leaves was determined before and after

heating, after spraying, and in the fourth group which served as control, 35 min. after heating, but without spraying. Data are given in Table 2.

Table 2

Washing out of Ammonia from Leaves of Wheat by Means of Spraying

Material	Fertilizer	Amount of ammonia nitrogen in mg per 1 g of dry leaf mass			
		Before heating	After heating	Before spraying	Without spraying
«Marquis»	NPK'	0.102	0.415	0.378	0.431
	NPK	0.074	0.410	0.368	0.386
	PK	0.076	0.346	0.299	0.407
	Without fert.	0.090	0.385	0.379	0.465

Only the leaves subjected to spraying show a reduced ammonia content. We are once more justified to ascert that the positive effect of spraying, especially under the conditions of high temperatures, consists in washing out of the plant's tissues toxic products of decomposition. After the experimental plants have been kept for 3 days under normal conditions, they showed a total restoration both of turgor and pigmentation in variants NPK and PK. The plants which were given an excess of nitrogen content in the soil (NPK') and those which received no fertilizers, perished owing to a reduced ability to resynthesize ammonia. The effect of fertilizers (NPK and PK) as factors increasing heat-resistance, should result, in the first place, in the production of a heat-resistant plant showing a high synthesizing ability.

2. Effect of Fertilizers and Spraying upon the Resistance of Wheats to a Prolonged Action of High Temperatures. Experiment 3. Wheats of varieties «Marquis», «Sarrubra» and var. *erythrospermum* 0341, at the phase of stalking—outset of heading, are treated during 5 days with a relative air humidity of 40—55%, and a temperature of 40—43°C, 4 hours every day. After heating, the plants were watered up to restoration of the original soil humidity (60% by weight). Two procedures of watering were applied: with and without washing. At the same time were studied the variations in water content in the leaves (the 3rd leaf from the top was cut off), as dependent on mode of watering. As a result of the experiment, we could evaluate the response of the plant to the effect of temperature as dependent on fertilizers and mode of watering, judging by its appearance. We proved unable to evaluate the yield, owing to the inevitable injuries of the ears occasioned during transportation of the vessels. Table 3 contains the results of 3 days of the experiment, those of the 4th and 5th day being identical.

In our experiment which was carried out under conditions of high humidity characteristic of naturally irrigated plots, too ([3]), the water loss by leaves proved insignificant; it is more pronounced in weakened plants (NPK' and without fertilizers). Spraying results in a quicker water supply of the leaf tissues (the difference is more conspicuous between 'NPK' variants and those given no fertilizers). However, the advantage of spraying can scarcely be accounted for by this insignificant variation of water content, the total water content showing high figures. We believe it to largely depend upon the freeing of the leaf from toxic products of decomposition. After 5 days of experiments, outstanding resistance is shown by the plants of the PK-variant, and particularly those given NPK under spraying.

Table 3

Water Content in Leaves as Dependent upon Mode of Watering (in % to raw weight)

Material	Fertilizer	1st day				2nd day				3rd day			
		1*	2*	3*	4*	1	2	3	4	1	2	3	4
«Sarrubra»	NPK'	82.17	74.19	76.14	74.50	82.73	76.53	80.44	76.40	80.01	74.22	78.39	72.22
	NPK	88.13	86.92	87.11	85.34	87.66	86.03	87.11	85.17	88.07	86.95	87.49	85 54
	PK	87.25	85.01	86.92	83.11	88.38	86.19	86.49	82.39	87.41	86.12	86.22	85 33
	Without fertil.	84.16	83.50	85.16	80.14	85.21	84.52	84.43	83.48	84.91	75.75	84.08	83.09

1*—before heating, 2*—after heating, 3*—under spraying, 4*—without spraying.

Our data may serve as interpretation of some phenomena observed in the practice of irrigational agronomy. Kostiakov and Fedorenko (3) point to the fact that cotton cultivated under spraying gives both qualitatively and quantitatively better yields as compared with those obtained under spontaneous watering. The same was pointed out by Chetkin (12) for potato. The authors especially emphasize the importance of spraying at the hot hours of the day.

Conclusions

1. The death of a plant exposed to high temperatures is due under natural conditions to disturbed metabolism, accumulation of toxic products of decomposition, ammonia, by which the plant is being poisoned.

2. The plant's resistance is determined by the resistance of its plasm complex to the effect of ammonia and to the ability of the cell to resynthesize the products of decomposition.

3. By using fertilizers which favourize the rearing of a healthy plant showing a high ability to synthesis, it is possible to increase the plant's resistance to high temperatures. The deficiency of nitrogen, and still more its excess (NPK') show a negative effect.

4. Spraying leads to washing out of ammonia from the plant's tissue. This is the reason why spraying should be preferred to other modes of watering, in particular, under conditions of a high temperature regime.

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PLANT PHYSIOLOGY

EFFECT OF FERTILIZERS AND SPRAYING ON PLANTS AFFECTED BY HOT DRY WIND

By V. F. ALTERGOT, F. V. SHATILOV and G. N. KHUNZARIDZE

(Communicated by A. A. Richter, Member of the Academy, 26. VII. 1939)

Most of the students used heretofore to pay attention mainly to the withering effect of the hot dry wind («sukhovey»). Thus, Maximov ([12]) attributes the final cause of the death of a plant affected by drought to coagulation of the plasm's colloids, due to dehydration. We are inclined to share Alexeev's opinion ([1]) that these rather common views are one-sided, we would say, simplified. To dispose of all the modern data on the biochemistry of the vegetative cell and to ignore the processes preceding coagulation of plasm colloids, means to ignore the real cause of the phenomenon.

According to modern data ([11,17]), a slight dehydration of the plant's tissue is sufficient to disturb its normal metabolism, which leads in the subsequent to profound protein decomposition. The knowledge of this fact makes us introduce important corrections into our interpretation of the causes of death of a plant affected by drought.

One of the authors has suggested a new explanation of the plant's death at high temperatures ([2,3]). The latter are assumed to lead to the prevalence in the cell of decomposition processes, to disturbance of nitrogen metabolism and accumulation of toxic ammonia products which poison the plant. It is natural to assume that the fatal influence of the hot dry wind, «sukhovey», should manifest itself, first of all, in the disturbance of normal metabolism and accumulation of toxic products of decomposition. According to our data ([3]), the physiological characters of hot dry wind resistance are the following: the plant's increased capacity to resynthesizing the products of decomposition and the water-adsorbing capacity of its tissues, connected with the former.

Three varieties of summer wheats*—Tatcher, v. *Melanopus* 069 and v. *lutescens* 062—were grown in a greenhouse at a humidity of 60% in terms of total moisture capacity of the soil. On account of our previous data ([3]), as well as of literary data available ([5]), we thought it of interest to test the effect of mineral fertilizers of various nitrogen content of the soil upon the resistance to hot dry wind. Within each variety the variants of fertilizers per vessel containing 9 kg soil, correction being made for the active element, were as follows:

* Seed material obtained from A. P. Shekhurdin.

1. NPK′—montan-nitre—10.5 g superphosphate —14.6 g silvinite —3 g Nitrogen excess
2. NPK — » 3.5 » » » 14.6 » » » 3 » Conventionally normal nitrogen content
3. PK — » 0 » » » 14.6 » » » 3 » Without nitrogen
4. Control—unfertilized.

Since the moment of tillering the plants of the variants which received NPK and PK could be easily distinguished by their height, development of the leaf surface and intensity of pigmentation.

Hot dry wind was reproduced artificially with the help of an apparatus*, consisting of a metallic tube 1.6 m long, inlet area—40 × 40 cm, outlet area—25 × 25 cm, mounted on legs 1.5 m high. By switching in an electrical heater, placed within the tube, and a motor which set a going the fan, one succeeded in producing a wind of any temperature, humidity and velocity desirable. The experiments were carried out in the open air, at sunny days. The plants in vessels were arranged in rows on a stand so that their green mass was exposed to the hot wind.

The plant's response to the treatment was evaluated by measuring the accumulation of ammonia, variation of the osmotic pressure, and water content in leaves. The determination of osmotic pressure was done by the cryoscopic method. The ammonia content in leaves was measured after Longi ([14]). The percent of water in leaves was found by drying them at 105—110°C to their constant weight.

1. Ammonia Accumulation in Plants Subjected to Hot Dry Wind, and Effect of Spraying upon Ammonia Content in Leaves. Experiment 1. Vessels containing wheats v. *lutescens* 062 and Tatcher at the phase tillering-outset of stalking are divided into 3 series. In the plants of the first series ammonia and water content in leaves is determined previous to the experiment. In the plants of the second series—after they were treated with hot dry wind during 4 hours. In the plants of the third series, kept under the same conditions as those of the second series, after a ten-minute spraying, and a subse-

Table 1

Material	Fertilizer	Wind temperature from 38 to 41°C. Relative wind humidity (for August)—from 15 to 20%					
		Amount of ammonia nitrogen per 1 g of dry leaf mass in mg			Water content in leaves to raw weight in %		
		Before hot dry wind	After hot dry wind	After spraying	Before hot dry wind	After hot dry wind	After spraying
V. *lutescens* 062	NPK′	0.049	0.138	0.031	80.42	60.88	74.29
	NPK	0.058	0.077	0.059	74.10	72.27	75.83
	PK	0.050	0.102	0.078	79.35	76.90	77.83
	Without fertil.	0.039	0.072	0.028	79.01	65.51	72.11

* The principal part of the apparatus obtained at the Saratov Salt Station.

quent total drying of the leaves in the open air during 20—25 min. Table 1 contains data referring to one variety.

Inspite of the small water loss by the leaves of the plants, especially in variants given NPK and PK, towards the end of the experiment withering proved rather considerable. We believe that the intense depression was due to advanced decomposition processes and to accumulation of ammonia which poisoned the plant. The compound phenomenon of hot dry wind involves two simultaneously operating factors—dehydration and high temperature, the effect of which is being mutually increased. This accounts for an earlier death of a plant affected by hot dry wind, as compared with that under the action of high temperature, but under conditions of high air humidity. Our experiments confirm once more the favourable effect of spraying upon the plant, which consists in washing out of toxic products of ammonia decomposition ([3],[4]).

Apparatus for creating an artificial hot dry wind (lateral view).

From the results of experiment 1 it may be seen that the high resistance to hot dry wind observed in plants, intensely developing under NPK and PK fertilizers, depends on their increased ability to resynthesize the products of decomposition, this ability being connected with a higher water retaining ability of their tissues. In this connexion it seemed of interest to investigate the variations in the osmotic pressure of the cell sap.

Experiment 2. Wheats of the sorts Tatcher and v. *lutescens* 062 at the phase of tillering-outset of stalking, the initial soil humidity being 40 and 60% of the total moisture capacity, were exposed to the effect of hot dry wind for 4 hours. The osmotic pressure of cell sap and water content in leaves were measured before and after treatment. In Table 2 data are given for v. *lutescens* 062.

Under favourable conditions of mineral nutrition (NPK and PK) the plants show an increase of osmotic pressure both before and after treatment, as compared with unfertilized ones. Owing to this peculiarity, they develop an outstanding resistance to the dehydrating effect of hot dry wind. These data, obtained by us as early as in 1937, were recently confirmed by Semakin ([13]).

2. Effect of Spraying upon Resistance of Wheats to Prolonged Influence of Hot Dry Wind. Experiment 3. Wheats of the sorts v. *Melanopus* 069 and v. *lutescens* 062 at the phase of tillering-outset of flowering were exposed to the action of hot dry wind during 3 subsequent days, 4 hours per day. After the experiment was ended, the soil was daily brought to its initial humidity, by watering the soil's surface without wetting the plants. The water content in leaves was determined before and after treatment (the 3rd leaf from the top was cut off), as well as 45 min. after the treatment was ended. Watering and total drying of the leaves took place within this period in the open air. In Table 3 are given data for 2 days of experiment with v. *lutescens* 062.

Table 2

Material	Fertilizer	Wind temperature from 37 to 41°C Relative wind humidity (for August)—from 16 to 19 %			
		Osmotic pressure in the cell sap in atm.		Water content in leaves in % to raw weight	
		Before treatment	After treatment	Before treatment	After treatment
		Soil humidity 60% to total moisture capacity			
V. *lutescens* 062	NPK	10.71	10.84	87.71	80.34
	PK	10.81	11.42	89.46	85.27
	Without fertiliz.	9.47	10.24	90.77	71.89
		Soil humidity 40% to total moisture capacity			
V. *lutescens* 062	NPK	11.02	12.86	84.71	84.87
	PK	11.93	13.18	86.40	85.80
	Without fertiliz.	9.08	10.54	87.71	79.71

The results point once more to a higher water-retaining power of plants of variants given NPK and PK. Spraying results in a quicker compensation of water deficiency in leaves. The opinions as to the importance of water absorbed by the plant's leaves are at variance ([15],[16],[18]). We believe that when

Table 3

Water Content in Leaves of Wheats Exposed to Hot Dry Wind, as Dependent on the Mode of Watering

Material	Fertilizer	2nd day				3rd day			
		Wind temperature from 38 to 41°C. Relative humidity of wind (for August) 12—20%. Soil humidity in vessels—60% to the total moisture capacity. Water content in leaves in % to raw weight							
		1*	2*	3*	4*	1	2	3	4
V. *lutescens* 062	NPK	74.61	64.45	65.22	60.07	76.61	62.34	64.19	60.92
	NPK	80.11	69.20	72.55	70.12	78.15	64.11	70.05	65.00
	PK	76.46	64.90	68.34	64.35	77.17	65.73	68.01	66.05
	Without fertiliz.	72.62	55.29	58.14	55.30	79.31	53.12	70.27	60.16

1*—before treatment, 2*—after treatment, 3*—after watering with spraying, 4*—after watering without spraying.

evaluating this phenomenon, it is necessary to take into account the ecological conditions of habitat and the physiological type of the plant. Adopting our interpretation of the plant's death due to drought, it should be assumed that the water absorbed by the leaves at spraying may act as a factor contributing to the restoration of the disturbed metabolism. It is impossible not to take into account the fact of microclimatic conditions becoming mil-

der, which was pointed out by Kostiakov and Fedorenko [8]. The conclusions drawn from experiments 1, 2 and 3 are fully confirmed by the evaluation of the final results—the conditions of the plants in the experiment 3, by the 10th day after the treatment with hot dry wind was stopped. Slightly injured proved the plants of the variant NPK and especially PK exposed to watering with a spray. Those watered without washing showed a considerable number of died off bottom leaves. Variants grown under excess of nitrogen or without fertilizers died, the response to hot dry wind being originally manifested in the leaves getting yellow and brown, while the tops of the stalks and ears became white. Similar injuries have been described in literature [6,7,9,10].

Conclusions

1. The harmful effect of dehydration of the vegetative cell exposed to the action of drought and hot dry wind consists, first of all, in the deviation of normal metabolism towards the prevalence of decomposition processes. Profound decomposition of proteins results in an accumulation of toxic ammonia products, by which the plants are poisoned. This capacity of dehydration and high temperatures to promote decomposition should be taken to account for the rapid death of plants exposed to hot dry wind.

2. It is possible to increase the resistance of plants to hot dry wind by using fertilizers (PK and NPK) and spraying.

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PLANT PHYSIOLOGY

TRIMMING AND REGENERATION OF ROOTS IN CULTIVATED PLANTS

By T. T. DEMIDENKO and V. V. KISSELEVA

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Specific effect of the basic nutritive elements may be easily seen on the external morphology of the overground parts of a plant organism. The question is somewhat complicated when we attempt to determine this effect on the root system which is within the soil. The question of the influence exerted by the basic nutritive substances upon the development and growth of the root system was the object of plant-growers and physiologists ([1–5]).

In order to grow high-yielding plants physiologists should study not only the effectiveness of each fertilizer, but, moreover, they should know the specific effect of the basic elements and of their combination upon development and yield. If the plants have greatly developed root system, they usually produce high yield, owing to the fact that they absorb with the aid of roots more nutritive substance from a greater mass of soil and get a sufficient water supply from deeper levels of the soil. Making soil mellow and applying additional fertilizers greatly disturb the root system, which undoubtedly has an unfavourable effect upon the general development of the plants. When no deep mellowing and adding of fertilizers are applied to tillable crops, the yield would surely greatly drop.

In connexion with the above-said we have conducted a series of experiments on the effect of the trimming of the root system. The experiment was made in water-cultures, in a nitrate-ammonium nutritive mixture; its pH varied from 5.5 to 6.5. This mixture proved to be very favourable for the growth and development of the cultures under experiment.

The scheme of the experiment was a rather simple one. The number of trimmings made during the summer was equal to 4. The trimmings were done at moments when the corresponding agrotechnical measures were taken under field conditions. The results are presented in Table 1.

Aside from water-cultures experiments on the effect of root trimming were conducted in lysimeters where sunflower plants were grown in soil. The results are represented in Table 2.

The following conclusions may be drawn from the Tables 1 and 2.

1. Root trimming conducted in water- or soil-cultures from 1 to 4 times during the summer has a negative effect upon the growth of the root system and of the overground parts and greatly reduces the yield of seeds in sunflower.

2. The oftener is done the root trimming, the more is its effect upon the yield in sunflower; this is connected with the great expenditure of plastic materials on the restoration of the injured root system.

Table 1

Effect of Root Trimming upon the Yield in Sunflower

Experimental scheme (water-cultures)	Quantity of root cut off (in g)	Weight of the dry mass	Yield of seeds	
			Abs.	Relat.
Normal culture without trimming	—	112.37	28.54	100.0
1st adding of fertilizers at the stage of 3 pairs of leaves	0.86	106.54	27.32	95.7
2nd adding of fertilizers before the formation of inflorescences	1.37	102.14	26.18	91.7
3rd adding of fertilizers during the formation of the inflorescences	1.68	96.35	26.01	91.1
4th adding of fertilizers, beginning of the flowering	2.25	92.21	25.18	88.2

3. Root trimming produces the strongest negative effect when done at the period of the strongest growth of the plant. Such a reaction is connected with the fact that organic materials are spent on regeneration of the root system, and normal course of the biochemical processes going on within the plant is disturbed.

Table 2

Effect of Root Trimming upon the Yield in Sunflower

Experimental scheme	Weight of the dry mass of the plant	Yield of seeds		% of oil in the kernel
		Abs.	Relat.	
Control, no root trimming	521.48	97.48	100.0	52.9
1st trimming at the stage of 3 pairs of leaves (15 cm far from the row)	501.86	95.70	98.2	51.6
2nd trimming before the formation of the inflorescences (20 cm far from the row)	496.37	93.12	95.5	51.4
3rd trimming during the formation of the inflorescences (30 cm far from the row)	492.25	90.38	92.7	51.3
4th trimming at the beginning of flowering (30 cm far from the row)	486.42	90.21	92.5	51.0

4. After trimming of the root system the plants both in water- and soil-cultures reduce transpiration, but after new rootlets are formed to replace the removed ones they stronger evaporate water than the control plants.

The data presented above may seem to speak against such important operations as soil mellowing and adding of fertilizers under field conditions; however, the practice of the foremen of high yields and of the Stachanowists has shown that high yields may be obtained with the aid of these agrotechnical methods. Keeping in mind the strong overflowing of the soil after the rain, formation of a crust and lowering of the life activity owing to shortage in oxygen within the soil and, therefore, to low production of nutritive materials, on the one hand, and to high consumption of nutritive substances, on the other, one should apply soil mellowing and additional fertilizers under field conditions, although care should be taken not to disturb the root system.

In connexion with the fact that adding of fertilizers under field conditions is mainly done with the aid of such fertilizers which contain P, N and

K which are introduced into the soil in various combinations, we attempted to follow up the effectiveness of the pure salts upon the restoration of the root system in sunflower, Indian corn, beet and perilla by immersing seedlings of various age into solution of various concentrations. For the sake of simplicity and clearness we shall present data on sunflower and Indian corn. The experimental conditions were as follows: plants were grown in tap water during 15 days, then they were transferred to glass-vessels containing nutritive solutions, 4 plants to each. Concentration of the solutions was equal to 0.001 mol. Prior to transfer of the seedlings to the nutritive substratum, we have counted the number of rootlets they had, and then made the trimming and immersed the plants into the solutions. The experiment was conducted in June, in 20 repetitions. We shall not treat here the remaining material.

Table 3

Effect of Nutritive Salts upon the Restoration of the Root System of Sunflower

Solutions	Average number of roots per one sunflower plant				Relative increase (in % of the control)
	before trimming	after trimming	after the exper.	addit. roots appeared	
Control—distilled water	43	11	33.0	22.0	100.0
$Ca(NO_3)_2$	43	11	65.0	54.0	246.5
$Ca(H_2PO_4)_2$	43	11	50.0	39.0	176.1
KCl	43	11	61.0	50.0	228.3
$Ca(NO_3)_2+Ca(H_2PO_4)_2$	43	11	59.0	48.0	217.3
$Ca(NO_3)_2+KCl$	43	11	48.0	37.0	167.1
$Ca(H_2PO_4)_2+KCl$	43	11	45.0	34.0	157.5
$Ca(NO_3)_2+Ca(H_2PO_4)_2+KCl$	43	11	35.0	24.0	110.5

Among the various salts $Ca(NO_3)_2$ produced the best effect upon the restoration of the root system in the young seedlings of sunflower under the given experimental conditions: the newly developed rootlets amounted to 246.5%. Rather effective proved KCl which also stimulated strong regeneration of the rootlets in sunflower, the number of the roots being increased by 228.3%. $Ca(H_2PO_4)_2$ assumed an intermediate position between the nitrates and kalium salts used in the experiment.

Among the paired combinations a rather favourable effect was produced by nitrates with phosphoric salts. Significantly worse is the effect upon the growth of the rootlets of NK and PK; still worse is the complete nutritive mixture where the number of appearing rootlets exceeded control only by 10.5%.

In case seedlings of Indian corn were immersed into solutions of salts after root trimming, the following results were obtained (Table 4).

The best effect upon the restoration of the root system in Indian corn was produced by the combination $Ca(NO_3)_2+KCl$, where the number of rootlets was increased by 195.1%. The solution of $Ca(NO_3)_2$ alone assumed the second place. Rather favourable is the effect upon restoration of the root system of the solution of KCl. Mixture of the two salts $Ca(NO_3)_2+Ca(H_2PO_4)_2$ produced the lowest increase in the number of rootlets in corn. Although the growth of the root system was stronger on single salts, the increase in vegetative mass was slower than on solutions containing PNK.

Table 4

Effect of Nutritive Salts upon the Restoration of the Roots in Corn

Solutions	Number of roots of Indian corn per 1 plant				Relative increase (in % of the control)
	before trimming	after trimming	after the exper.	addit. roots appeared	
Control—distilled water	65	13	196	183	100.0
$Ca(NO_3)_2$	65	13	343	330	189.3
$Ca(H_2PO_4)_2$	65	13	293	280	153.0
$Ca(NO_3)_2+Ca(H_2PO_4)_2$	65	13	257	243	132.8
KCl	65	13	303	295	161.2
$Ca(NO_3)_2+KCl$	65	13	370	357	195.1
$Ca(H_2PO_4)_2+KCl$	65	13	274	261	142.6

Our studies would be incomplete, had we conducted no experiments in soil; this was done in isolated soil-sand cultures of sunflower and Indian corn. Root system was trimmed at various distances, and the fertilizer was introduced into the sphere of localization of the root system. It appeared that within 5—10 days abundant root-net was formed there where the fertilizer was placed. Therefore, when soil mellowing and adding of fertilizers are combined in a rational manner, we make damage to plants by a partial injury of their root system; however, by opening way for oxygen to the roots through soil mellowing and by improving nutrition by additional fertilizers, we create very favourable conditions which lead to a sharp increase in yield, provided the two operations are combined in a right manner.

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PLANT PHYSIOLOGY

IMPORTANCE OF TEMPERATURE CONDITIONS IN THE HARDENING OF CITROUS PLANTS

By S. M. IVANOV

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It has been established that citrous, as well as all other plants, are capable of increasing their frost-resistance considerably during the hardening process ([1],[5]), but this process has not been studied enough as yet.

The purpose of this communication is to put forward the main results of an investigation conducted in 1937—1938 to ascertain the influence of temperature conditions on the hardening of citrous plants.

The subjects of study were monoclone plants of lemon, orange and Unshiu mandarin grafted on *Poncirus trifoliata*. The plants were grown in pots and hardened in cooled chmbers. While hardening, the plants were placed in chambers for the night, and in daytime they were kept under natural temperature and light conditions. In order to determine the nature of the changes which take place in the plants subjected to hardening, the sugar and water content and the quantity of reduced glutathione in the leaves were determined; and in one of the experiments the activity of catalase and the value of its temperature coefficient (Q_{10}) were taken into account. The reason for this were indications on the relation between the frost-resistance of plants and these indices ([1],[3],[4],[6],[8],[9]).

The aim of the first experiment was to determine the nature of hardening of the species of plants studied at positive temperatures. The plants were hardened at +6° and at +2°C for 8 nights. The natural temperature conditions during the experiment were: the day maximum varied within the interval 14.2—24.4°, while the minimum temperatures fluctuated from 8.5 to 11.6°C.

Determination of the frost-resistance of the plants after hardening showed, that the lower the positive temperature during the night, the better the plants are hardened. It was found out, moreover, that the degrees of hardening of the plant species in question vary greatly. The frost-resistance increased most in lemons, considerably less in oranges and still less in mandarins (Table 1).

Determination of the contents of the reduced glutathione (Table 1) showed, that the increase in frost-resistance during the hardening of the plants is due to a decrease in the amount of glutathione.

Hardening caused some increase in the sugar content in all the species in question, but this was not observed in all cases. The relation between the frost-resistance and the quantity of sugars in the plants showed considerable deviations. The total amount of water in the leaves changed somewhat during hardening, but it seems impossible to determine the relation of these chan-

Table 1

Species and variety	Variant	Freezing t°C	% damage		Quantity of reduced glutathione		Quantity of sugar in % per abs. dry weight			% of water in leaves	Activity of catalase	t° coeff. of catalase (Q_{10})
			leaves	branches	mg per 100 g leaves	%	monosugar	sucrose	total sugar			
Novo-Afon lemon	Control	−6.5	100	86	123.46	100	2.87	6.10	9.30	63.2	12.1	2.14
	+6°,8 nights	−6.5	98	32	119.84	95	3.06	4.89	8.21	62.1	13.7	2.21
	+2°,8 »	−6.5	70	6	84.02	68	5.82	5.90	12.03	63.4	7.5	2.36
Washing-ton Navel orange	Control	−8.5	100	90	108.86	100	3.05	5.57	8.91	66.5	12.3	2.04
	+6°.8 nights	−8.5	100	81	101.20	92	3.86	3.67	7.72	66.1	16.2	1.90
	+2°,8 »	−8.5	100	68	78.79	72	4.92	5.57	10.78	65.5	—	—
Unshiu mandarin	Control	−9.5	100	99	76.66	100	2.91	5.53	8.73	62.5	17.0	2.03
	+6°.8 nights	−9.5	100	94	75.05	98	4.47	4.62	9.33	—	20.5	1.93
	+2°,8 »	−9.5	100	89	74.12	97	4.10	5.00	9.36	64.9	9.7	2.24

ges to the frost-resistance of the plants. Determination of the catalase activity and its temperature coefficient showed that these indices are not related to the frost-resistance of the plant. These hardening conditions described above correspond to the conditions of the 1st phase of hardening.

A second experiment was performed with the same subjects, in order to ascertain the nature of hardening under the action of negative temperatures, which are necessary for the 2nd phase of hardening. Plants hardened at+2°C for 8 nights were subjected to further hardening at—2° for another 8 nights. During the daytime the plants were under natural conditions and their mean maximum temperature during the experiment was 15.3°; the control plants were hardened under minimum temperature conditions varying from 7.8 to 14.6°.

Table 2

Species and variety	Variant	Freezing t°C	% damage		Quantity of reduced glutathione in mg per 100 g of leaves	Quantity of sugar in leaves in % per abs. dry weight			% of water in leaves
			leaves	branches		monosugar	sucrose	total sugar	
Novo-Afon lemon	Control	— 6.5	26	7	117.73	2.93	3.15	6.25	63.1
	−2°,8 nights	— 6.5	23	3	99.17	8.44	6.71	15.50	63.9
Washington Navel orange	Control	— 9.0	100	89	109.35	3.62	4.85	8.73	68.3
	−2°,8 nights	— 9.0	97	22	65.77	6.43	6.12	12.87	65.1
Unshiu mandarin	Control	−10.0	100	89	81.51	3.35	4.77	8.37	62.4
	−2°,8 nights	−10.0	86	28	42.77	4.73	5.93	10.97	64.5

The results of evaluation of frost-resistance of plants, measurements of sugar, water and reduced glutathione content in the leaves are summarized in Table 2.

Table 2 shows, that negative temperatures which cause no damage, contribute to a considerable hardening of the citrous plants, too. Moreover, the species under comparison differ greatly in their increase of frost-resistance, but their order, according to the degree of resistance, is inverse to that observed in the case of hardening at positive temperatures. As a result of hardening the quantity of reduced glutathione in the plants proved to decrease, while this showed considerable sugar accumulation. The degree of decrease of the reduced glutathione is connected with the increase of the frost-resistance of the plants, but the relation between frost-resistance and the increase of the sugar content which was quite pronounced in this case, has not been established. In order to get a clearer idea of the nature of the hardening of citrous plants under positive and negative temperatures, let us compare the results of the first and the second experiments.

For sake of convenience we shall compare the figures which characterize: the decrease in damage of the plants, the decrease in the quantity of reduced glutathione and the percentage increase of the sugars content in the species in question, as a result of hardening at+2° and at—2°, respectively (Table 3).

Table 3

Species and variety	Hardening at+2°, 8 nights			Hardening at—2°, 8 nights		
	Decrease in % damage of the branches	Decrease in quantity of reduced glutathione	Increase in sugar content	Decrease in % damage of the branches	Decrease in quantity of red. glutath. in leaves (% to the control)	Increase in sugar content
Novo-Afon lemon	80	32	2.73	4	17	9.25
Washington Navel orange .	22	28	1.87	67	40	4.14
Unshiu mandarin	10	3	0.63	61	49	2.50

An examination of these data shows that although citrous plants harden both at positive and at negative temperatures, different plant species react very differently to temperature influences. The lemon attains its highest frost-resistance when hardened at positive temperatures (+2°), but its frost-resistance increases very little when hardened at negative temperatures (—2°); the mandarin and orange plants, on the other hand, harden less at positive temperatures than at negative temperatures. This is why we had changed the order of the species, according to their degree of frost-resistance increase as a result of hardening at—2° in comparison with hardening at+2°.

These species differ also in their hardening capacities. Under equal hardening conditions (8 nights at+2° and just as long at—2°) the frost-resistance of the lemons increased somewhat more in comparison with the control than that of the mandarins which show a considerably higher relative frost-resistance. This points to that the various frost-resistance of plants is determined not only by their hardening capacities, but also depends to a great

extent upon the capacities of the plants of the species in question which are formed during its historic development.

The main internal cause of the frost-resistance increase during hardening is the decrease in the activeness of growth processes and in the functional activity of the cells which is connected with growth. This is shown by the decrease in the amount of reduced glutathione in the plants during hardening corresponding to the frost-resistance increase in the plants. The energy decrease during the growth processes, as has been established ([3]), is connected with changes in the properties of the plasm, which results in an increasing resistance to the deformative activity of low temperature.

The increase in the sugar content and also that of other osmotic active substances, whose protective rôle has been established by a number of studies ([4,8,9]), causes an increase in the frost-resistance of citrous plants, but is not the main cause of frost-resistance and does not always coincide in trend with the changes in the state of the plasm, which determine its resistance to the injurious action of low temperature. There is also no relation between the frost-resistance of plants and the activity of catalase and the value of its temperature coefficient.

The hardening of plants at positive and negative temperatures are considered two qualitatively different processes following one another—the 1st and 2nd phases of hardening ([7]).

This study of the hardening of citrous plants shows, that the internal changes which take place in plants under the influence of positive and negative temperatures differ quantitatively and not qualitatively. This permits us to assume that the hardening process in citrous plants is undivisible as to the nature of its internal change. It is also possible that the division of the hardening process into two phases is altogether conventional and actually does not exist, since it was done on the basis of the difference in the external conditions of hardening and not the internal changes which determine the frost-resistance increase in the plants.

Ascertaining the nature of hardening and the internal causes of the increase of frost-resistance, permits us to plan ways of working out new methods to actively control the frost-resistance in citrous plants.

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PLANT PHYSIOLOGY

INFLUENCE OF LIGHT INTENSITY ON THE HARDENING OF CITROUS PLANTS

By S. M. IVANOV

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The dependence of the hardening of different species of citrous plants upon the temperature conditions has been quite well studied ([1],[2]), but the problem of the influence of light intensity on their hardening still remains not clear enough, although it is of particular importance for these plants on account of their specificity, growth conditions and method of cultivation.

It has been established, that the main internal cause of frost-resistance in citrous plants is the state of the plasm, which is a result of the decrease in the functional activity of the cells in connexion with their growth, while accumulation of sugars increases the frost-resistance of the plants without determining it ([3]). Therefore, the effect of light conditions on hardening should be examined not only from the point of view of its influence on photosynthesis and the content of soluble carbohydrates, but also in relation to the growth processes which determine the state of frost-resistance of the plasm. It was in this field that we undertook to study this problem.

In 1937—1938 it was observed, that if lemon, mandarin and orange plants were shaded during hardening for 8 days with three layers of gauze, their frost-resistance increased noticeably. This permitted us to assume, that a decrease in light intensity improves the hardening process not only in lemons, but also in other citrous plants which require even more light.

In order to check this assumption, the study of this problem was continued in the beginning of 1938. As material served 10—12-year-old summer Unshiu mandarin plants with well developed crowns. The branches of the south and north parts of the crowns of these plants which were under different light conditions, were compared. The relative frost-resistance of branches of 1937 summer growth, the content of reduced glutathione in the leaves and bast which characterizes the state of activity of the cells in connexion with their growth, and the quantity of sugars in the leaves and branches were determined. In order to characterize the thermic state of these parts of the crown, the temperature of the leaves was determined on a sunny day by means of a thermocouple. It was found that when the mean air temperature in the plant's crown was 12.2°C, the mean temperature of the leaves of the south part of the crown was 17.8°; at the same time the leaves of the north part of the crown had a mean temperature of 12.8°.

Data on the frost-resistance of the branches in question, their sugar content and the amount of reduced glutathione in them are given in Table 1.

Table 1

	% damage		Quantity of reduced glutathione		Total of sugars in % per abs. dry weight	
	branches	leaves	bast	leaves	branches	leaves
North part of the crown	0	29	18.56	75.05	9.14	7.73
South part of the crown	10	81	20.58	91.19	7.23	5.94

From the above it follows that the frost-resistance of branches from the north part of the crown was considerably greater than that of branches from the south part of the crown. It was noticed, moreover, that branches from the north part of the crown contain less reduced glutathione than branches from the south part. This shows that, while growing, the functional activity of the cells is more intensive as a result of higher temperature in the branches of the south part of the crown.

Determination of the sugar total shows, that there is less of it in the branches and leaves of the south side than in those of the north side. Therefore, it is the unlike light conditions in the north and south parts of the crown that cause different changes in their frost-resistance. The fact that the north part of the crown is more frost-resistant is due, on the one hand, to the growth processes being less active and to the increase in the sugar content, on the other.

In the next experiment lemon, orange and Unshiu mandarin plants grown in pots were placed under different light conditions during the natural hardening period. Some of the plants (10 of each species) were placed on a platform open on all sides, others were put in the shade of trees and exposed to direct sunlight only during the early hours of the day; the rest of the time they were kept in diffused light. In the middle of December, 1938, the frost-resistance of these plants and the reduced glutathione and sugar contents in the leaves were determined. The results given in Table 2 show that weak illumination increased the frost-resistance of the plants. In the controls 66% of all the leaves and 23% of the branches (of the total length of the whole plant) perished at —7°C. The plants which were hardened at weak illumination lost only 50% of their leaves and 4% of their branches (Table 2).

Table 2

Species and variety	Freezing t°C	Light conditions	% damage		Quantity of reduced glutath. in mg per 100 g of leaves	Total of sugars (in % per abs. dry weight of leaves)
			leaves	branches		
Novo-Afon lemon	— 7	Natural light	66	23	328.04	11.17
		Weak light	50	4	282.54	8.86
Orange (seedlings)	— 8	Natural light	22	2	209.91	9.30
		Weak light	15	2	193.68	10.09
Unshiu mandarin	—11	Natural light	100	73	116.21	13.72
		Weak light	100	65	68.59	11.41

A comparison of the morphologically homogeneous parts of the plants, according to their dergee of damage, disclosed even more pronounced differences. Thus, in the control lemon plants, for nstance, the branches of summer growth froze to 34% of their total length, the branches of the spring growth—17% and the stem—4%; while in the plants which had been weakly illuminated, only 4% of the branches of summer growth were damaged, while the branches of summer growth and the stem remained untouched.

The frost-resistance of mandarin and orange plants also increased as a result of weakened illumination, but less than in lemon plants; oranges reacted weakest of all.

That these differences in the frost-resistance of plants are a result of changes in their internal state, follows from the determination of the sugar and reduced glutathione content in the leaves. Weak illumination caused considerable decrease in reduced glutathione in all the species of plants mentioned. In the lemon and mandarin plants, moreover, the sugar content also decreased.

In comparing the changes in frost-resistance and the reduced glutathione and sugar contents, it may be observed that increase in frost-resistance is connected with decrease in the content of reduced glutathione. This relation is not disturbed even when the sugar content increases, as was observed in lemon and mandarin plants.

The results of these experiments permit us to consider that the hardening of citrous plants is determined not only by the surrounding temperature conditions, but also to a considerable degree by the light intensity. Light intensity acts on hardening in two ways: on the one hand, it changes the temperature of the plant, thus changing the activeness of the growth processes; on the other hand, it affects the energy of photosynthesis and increases the content of sugars, which raise the frost-resistance at optimal illumination intensity. The main cause for the increase in frost-resistance are the plasm changes in connexion with the decrease in activeness of the growth processes in the plants. These changes result in an increase of frost-resistance, whether the sugar content increases or even if it decreases somewhat.

Different species of citrous plants respond to variation in light intensity in a different way. Of all the species which we compared the lemon was the most plastic.

The nature of the relation between the hardening of citrous plants and the illumination intensity established by us accounts for the freezing of the south and south-east parts of the crowns of citrous and fruit trees. Usually, this is considered to be due to the fact that after freezing the south part of the crown thaws out more quickly under the action of the sun's rays. Actually, as may be concluded from the above, the south and north parts of the crown differ in their degrees of frost-resistance, because the process of hardening and the loss of hardiness assume a different course which in its turn is due to unlike illumination intensity during the pre-frost period.

Besides this, the discovered relation between the hardening of citrous plants and the illumination intensity gives ground to work out in more detail some further procedures of cultivating citrous plants, and for instance, a method is being planned for increasing the effectiveness of individual coverings on lemons for protecting them from frost.

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MICROBIOLOGY

LOCATION OF THE AZOTOBACTER IN FRESH-WATER BASINS

By A. G. SADIMOVSKAJA-RODINA

(Communicated by S. A. Zernov, Member of the Academy, 24.VI.1939)

That the azotobacter is to be found in the water and soils of various fresh-water basins has been ascertained by several authors. This as well as the effect which the azotobacter is known to have on the fertility of soils, led to the assumption that the azotobacter plays an important part in influencing the productivity of water basins.

However, the azotobacter having been found in small quantities in isolated samples, this assumption so far remains unsubstantiated. Recent works speak of the scarcity of this microorganism in water basins ([3]) and of the difficulty of discovering it ([5]).

The disparity between the results yielded by the searches for the azotobacter, on the one hand, and the theoretical assumptions and chemical data on the nitrogen balance, on the other hand, has led some authors (Baier) to the conclusion, that the media used in the search for the azotobacter was inappropriate, and others, that it was necessary to return to the idea of the possibility of nitrogen being fixed by algae ([1]). In endeavouring to solve the problem by a selection of nutritive media, Baier undertook a series of experiments with various nutritive elements, as a result of which he believes to have obtained a medium which contains all that is necessary for the development of the azotobacter.

In view of these contradictory opinions as to the part played by azotobacter in water basins, it was decided to study the Krasnogorsk Lake in the Leningrad region with a view of ascertaining whether or not it contains azotobacter. All the cultures made with water or soil from the open lake, with the exception of one, proved to contain no azotobacter, although both Baier's an Beyerink's media were used.

However, samples of bloom taken at the same time from the submersed part of algae have shown, where the azotobacter was to be looked for in the lake. The introduction into Baier's or Beyerink's media of a small piece of the submersed part of algae or the bloom of the latter, or else a piece of leaf that was immersed in water and taken from a tree that has been growing near the water or lying in the water, was invariably productive of a rich growth of azotobacter. Under the microscope the bloom of aquatic plants is seen to contain azotobacter, while the samples of the water become covered with a thin oily film on the third day.

Thus, the aquatic plants, such as reeds, mare's-nest, water-lily and others, which grow in abundance along the shores of the Krasnogorsk Lake, are the

seat of the azotobacter. And so are the *Chara*, *Litorella* and *Fontinalis* which cover the bed of the lake in its shallow parts. The *Cladophora* which cover the stones on the shore line, contain enormous quantities of these nitrogen fixing microorganisms.

The azotobacter was discovered on the following plants: *Phragmites communis*, *Scirpus lacustris*, *Butomus umbellatus*, *Equisetum limosum*, *Nymphaea candida*, *Nuphar luteum*, *Poligonum amphibium*, *Potamogeton natans*, *Pot. praelongus*, *Pot. perfoliatus*, *Pot. lucens*, *Pot. pusillus*, *Ranunculus circinatus*, *Sagittaria sagittaefolia*, *Myriophyllum spicatum*, *Utricularia vulgatus*, *Elodea canadensis*, *Chara*, *Litorella*, *Fontinalis*, *Cladophora*.

It should be noted that colonies of the azotobacter have been found on all of these plants, but none was found on dead plants in an advanced stage of decay. In alga zones the azotobacter has been found both in the water and in the bed (indicator 1—0.1 g).

In order to make sure that the presence of azotobacter is generally connected with aquatic plants and that data obtained with the Krasnogorsk Lake are not exceptional, samples were taken of the plants growing in the river Luga. Luga, a narrow and shallow river with a very rapid current, flows at a distance of 4 km from the lake with which, however, it has no connexion. Its banks and shallows are covered with various plants such as *Sparganium* L., *Potamogeton* Tourn., water-lilies and *Nymphaeaceae*. It was found that even in running water the surface of the submersed parts of plants contained enormous numbers of azotobacter colonies, just as those in the inclosed waters of the Krasnogorsk Lake.

Thus, nitrogen fixing organisms are to be found on aquatic plants not only in lakes, but also in rivers.

We were unable to discover in works dealing with this subject any reference to the presence of the azotobacter in such great numbers in the shallow zones of fresh-water basins. That the azotobacter is to be found on the surface of sea-weeds has been known long ago from the works of Keutner, Benecke, Keding, Issachenko ([2]) and others. Reinke pointed out the existence of symbiosis of azotobacter and sea-weeds. The azotobacter has also been found on fresh-water plants, such as the *Spirogyra* and *Volvox globator*. Fischer ([8]) refers to nitrogen fixing organisms having been found by him on *Riccia*, *Lemna* and *Salvinia*, but he does not say what kind of organisms they were. Fischer ascribed an important part in the fixing nitrogen in water basins to the *Pneumonia* group of bacteria. While studying *Elodea* and *Potamogeton* Lantzsch, on one occasion, discovered *B. turcosum* which is capable of fixing nitrogen ([9]). These data from Lantzsch's work are cited in a generalized form by Demoll ([7]). This is all we could find in literature on this subject.

The number of azotobacter found on plants in summer time is enormous.

It may be assumed that shallow water zones and particularly aquatic plant zones are seats where nitrogen is being intensively fixed, which in the long run should lead to the water being enriched with nitrogen compounds. Generally, however, the process of such compounds passing into the water is so far not quite clear([10]).

On the surface of plants, as shown by microscopic examination of the bloom taken from them, there are enormous quantities of various protozoa, mainly of *Ciliata*. In the cultures sown with the material taken from aquatic plants, after the azotobacter has formed a film on the surface of the nutritive medium, one could observe an intense development of protozoa which often almost completely destroyed the azotobacter in the course of a few days. For this reason the culture had to be frequently changed and a constant microscopical control kept. The consumption of the azotobacter in the culture by protozoa could always be observed under the microscope. It is

possible, as suggested by Moler([4]), that *Ciliata* play a certain part in the process of nitrogen compounds passing into the water. Cutler and Bal([6]) also refer to *Ciliata* as a factor in this process.

According to our observations, the azotobacter remains on the plants until late in the autumn when the aquatic plants die off. The azotobacter was discovered in 40% of the samples on October 21. Early in the spring, material taken from young and partly from last year's plants showed the development of the azotobacter.

In the cultures sown with the bloom taken from plants, various forms of azotobacter were observed both in the summer and autumn: larger forms approaching the *Az. agilis* and the fairly large—*Az. chroococcum* which produced typical brown film. A few strains of *Az. chroococcum* have been isolated which showed a pronounced nitrogen fixing ability.

During summer time, in the bloom taken from plants along with the azotobacter another nitrogen fixing organism was discovered: *Clostridium Pasteurianum*.

As the major part of our work has been done both with Baier's medium and the two Beyerink's media, this enabled us to compare the fitness of each of them as a means of discovering the aquatic strains of the azotobacter. To Beyerink's media we have in each case added an extract of slime. In 51 cases (79.66%) the results were the same, in 13 cases (20.34%) the results proved at variance. In 10 (15.62%) out of these 13 cases only Beyerink's media showed development, while in the remaining 3 cases (4.72%) only Baier's media gave results. Thus, our study has shown that Baier's media offer no particular advantages over Beyerink's media provided an extract of slime is added to the latter.

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MORPHOLOGY

COMPARATIVE MORPHOLOGICAL STUDY OF THE STRUCTURE OF THE LENS RESTORED FROM THE BORDER OF THE IRIS IN SOME AMPHIBIA

By M. F. NIKITENKO

(Communicated by I. I. Schmalhausen, Member of the Academy, 1. VIII. 1939)

After it has become evident that there is a connexion between the retina and the lens which grows from the upper border of the iris ([6],[2]), the need arose for a comparative study of the reconstitution of the lens in various species of amphibia.

The object of this study was more fully to elucidate this process on the basis of a comparative morphological analysis of various species so as to establish certain general laws. As Spemann had already noted in his last communication ([5]), it was of particular interest and importance to study this process in the *Anura* which so far has not been done in detail. In this connexion a great deal of work was done by myself in the summer of 1937 and 1938, on the basis of which our present communication is made.

I removed the lens in different species (*Rana esculenta*, *R. temporaria*, *R. arvalis*, *Bombina bombina*, *Pelobates fuscus*, *Bufo bufo* and *B. viridis*) and kept the animals operated upon for various lengths of time with a view of studying the restoration process at its various stages. The subjects under test were tadpoles at various phases of development as well as metamorphosed animals. I have tentatively divided the process in the following four stages which mark different morphological and functional conditions of the eyecup: 1) the pre-functional stage, i. e. the stage preceding the clarification of the cornea; 2) the larval stage; 3) the metamorphosis stage; 4) the adult stage.

During the pre-functional stage, the removal of the normally developing lens in most cases led to the growth of a new lens in all the previously enumerated species, provided the eyecup remained otherwise undamaged. It may be noted in passing that no strict localization was observed in the *Anura* with regard to the appearance of the new lens. The latter may grow either on the upper, lower or the side borders of the eyecup, and sometimes it even grows simultaneously on both the upper and lower borders.

It is of interest to note that in all the species investigated by us the restoration of the lens during the first stage occurred in an almost equal number of cases.

This might be taken to mean that at this stage the eyecup of all the species tested is in an equal degree endowed with the power to induce lens growth.

In the light of these data and the evidence proved by V. Popov, Lazarev's assertion[1] that the power of lens-formation varies according to the species becomes objectionable.

During the second stage the removal of the normally developed lens likewise led to the growth of a new lens from the border of the iris in all the species, but during this stage the number of cases, in which the lens was restored, differed in the different species. *B. bufo*, *R. arvalis* and *B. viridis* showed the greatest number of such cases. Successful restoration was also frequent in *B. bombina*.

During the third stage the restoration of the lens was observed by me only in the *B. bufo* and *P. fuscus*. In the operated eye of the *B. bombina* and *R. arvalis* lenses were also observed, but these were well differentiated and had no connexion with iris, so that it was very difficult to form an opinion as to their origin.

The *B. viridis*, we regret to say, has not been studied in the third stage.

During the fourth stage no definite restoration of the lens was observed in any of species under study. In the *B. bufo* one could observe the formation of lentoids and the regeneration of the lens from the remains of the lens. In the *B. bombina* pieces of the incompletely removed lens grew roundish assuming the shape of a small lens.

No such a process was observed in the other species. Thus, the question whether the restoration of the lens is possible in the investigated species during the fourth period remains unsolved.

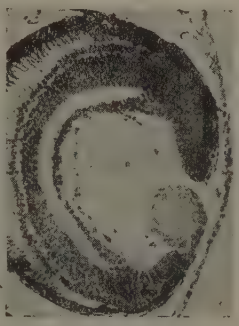

Fig. 1. Restoration of the lens from border of the iris in a tadpole of *R. esculenta* at the second stage (2—8. VI. 1938).

Fig. 2. Restoration of the lens from the border of the iris in a tadpole of *P. fuscus* at the second stage (15—20. VI. 1938).

The general development, the absolute and relative size of the restored lens which grows from the border of the iris differs in different species. These aspects of the development of the lens are easy to understand, since the rate of development of the tadpoles of frog as well as their size vary greatly in various species.

It is interesting to note that the morphological structure, phases and rate of the restoration of the lens also differ in some of the species, and these differences correspond to the differences which are observed during the normal or experimental development of the lens from the ectoderm.

In the case of *R. esculenta* and *B. bombina* the vesicle, after it is formed at the edge of the iris and becomes separated (Fig. 1), is transformed into a little ball with unequal walls and an eccentrically lying cavity, in which the proximal part is transformed into the fibrous part. In the *P. fuscus*, however, these processes are different. In some of the tadpoles of this species, the little ball originating at the edge of the iris rapidly becomes separated and grows into a larger vesicle with walls of almost equal thickness. The central cavity of this vesicle is during a long period filled with undifferentiated cells containing pigments (Fig. 2). This vesicle which very much

resembles a little ball and under normal conditions grows from the ectoderm, is differentiated into fibres and into the lens epithelium considerably later than in other species.

In the case of *B. viridis* the lens which grows out of the border of iris has the shape of a little ball with a very small inner cavity and walls of almost equal thickness, in which the cells are radially arranged.

In the case of *B. bufo* the epithelium of the restored lens is very strong and firm, particularly in the distal part of the lens. The fibrous nucleus is formed of large fibres not always regularly arranged.

In the case of the *R. arvalis* a large fibrous kernel covered with a thick epithelium with spherical cells, the nuclei of which are not always radially arranged, rapidly develops in the restored lens.

In the *R. temporaria* the cavity of the formed vesicle is sometimes preserved for a very long time and is clearly noticeable even in the lens after it has separated from the iris; it divides the epithelial part of the lens which is mainly formed in the distal part of the lens, from the strong fibrous kernel developing proximally.

It will be obvious that there are certain species specific differences in the structure and differentiation phases of the lens which grows out of the border of the iris.

Yet, these differences are not always and not in all cases clearly expressed. A point which appears to be worthy of note is that these specific differences in the structure of the restored lens, the phases and rapidity of differentiation run nearly parallel to the structure and differentiation phases of the lens which grows from the ectoderm under normal or experimental conditions. This is particularly evident when we compare the growth of the lens from the ectoderm and from the border of the iris in *P. fuscus*.

A great resemblance is also revealed in *B. viridis* and *R. esculenta*. In other *Anura* no distinct typical symptoms being observed in the structure of the lens, the variations are more considerable. An experienced worker, however, will succeed in discovering certain differences marking the species.

Thus, a number of species specific differences is observed in amphibia with regard to the restoration of the lens from the border of the iris and its development from the ectoderm. These variations are evidently based on the specific effect of the tissues forming the new lens and mainly on the specific effect of the retina inducing the growth of the lens. This species specific effect of the retina is reported in the works by Popov, Kisselev, Nikitenko and Chanturishvili (4): under the effect of the cup from *P. fuscus* a lens with a structure typical of the *P. fuscus* was being formed in the epithelium of the *R. esculenta*.

From this it follows that if the question as to whether the development of the lens is determined specifically by the eyecup has been solved in the negative and «the entire question of variation of species in this matter is reduced to variations in the percentage of the lenses that are being formed, these variations being evidently based on the fact that the determination of the epithelium sets in at different times in different individuals»(3), nevertheless, it is quite probable that there is a species specific variation in the rate of development, differentiation phases and morphological structure of the lens at the earlier stages of the development of the lens.

Another important implication of our data is that the similarity in the differentiation phases of the lens developing from the iris and from the epithelium in the various species testifies to the identity of both forms of lens formation.

In one of my works written in 1937 I have made the assumption that the development of the new lens from the iris is a process of induction rather than regeneration, i. e. a process caused by the effect of the retina. The observations communicated here appear to furnish new evidence to support this view.

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PALEONTOLOGY

CONTRIBUTION TO THE QUESTION OF ORIGIN OF CASPIAN MOLLUSKS

By V. P. KOLESNIKOV

(Communicated by A. D. Arkhangelsky, Member of the Academy, 28. VIII. 1939)

The taxonomy of Caspian mollusks is very poorly worked out. This deficiency is especially keenly felt by geologists engaged in the problem of distribution of old-Caspian deposits. The necessity for an improved classification of Caspian mollusks has long been pressing, but the solution of the question is facing serious difficulties, since the mollusks concerned show exceptional diversity. At the same time this peculiarity of theirs furnishes the paleontologists a wealth of material for studying the development of the fauna.

The formation of each species has been the outcome of a number of factors, the understanding of which is necessary for a successful study of mollusks. On the other hand, the study of the development of each species furnishes new material for the working up geological history.

When raising the question of origin of Caspian mollusks, we are first of all tempted to reveal the species which were inherited by the Caspian Sea from the Tertiary Caspian basin. It is known[1] that during the post-Pontian time in the Caspian region there was laid down a peculiar productive (Balakhan) deposition bearing practically no shells, except for the occasional occurrence of fresh-water forms. The beginning of the Akchagyl era was marked by the intrusion into the same region of the brackish-water fauna, foreign to the South Russian Miocene and Pliocene. The monographic analysis (V. Kolesnikov, «Akchagyl Mollusks, Paleontology of USSR», manuscript) of this fauna has shown that *Dreissensia* from the group *polymorpha* and *rostriformis* did not live in the Akchagyl Sea proper, but inhabited rivers discharging their waters into it, and possibly, invaded the regions of lowest salinity of the Northern bay (the Volga provinces). After the subsidence of the Akchagyl Sea and considerable freshening of its waters, the formation of the Apsheron fauna has begun, showing approximately the same generic composition as the contemporary Caspian.

The Apsheron molluskan fauna is heterogeneous by origin. It falls into 3 principal groups:

1) Greatly modified remains of the Akchagyl Sea population: *Dreissensia carinatocurvata* Sinz., *Hyrcania* (*Didacna* Andrus.), *Apscheronia*, *Melania*, *Clessiniola*, *Adacna* and *Micromelania*.

2) Mollusks which had immigrated into the freshened Apsheron basin from rivers and lakes: *Dreissensia distincta* Andrus., *D. polymorpha* Andrus., *Corbicula*, *Melanopsis*, *Limnaea*, *Caspia* and *Nematurella*.

3) Greatly modified immigrants from the Black Sea region: *Monodacna*, *Pseudocatillus*, *Didacnomya* and *Dressensiidae*, related to *Dreissensia anisoconcha* Andrus. and to *D. tenuissima* Sinz.

While tracing the vertical range of these groups, it becomes apparent that the lower Apsheron strata contain but a few species (25) of the first and second group; in the middle Apsheron strata they are associated with species of the 3rd group; in the upper Apsheron strata the total number of species undergoes a sharp decrease (the middle Apsheron having 60 and the upper one 39 of them).

These data shed some new light on the history of the development of the Apsheron Sea. The beginning of the Apsheronian era was marked by a sharp intensification of the movements of the earth's crust which caused a great reduction of the sea area, at the expense of the waters drained into the regions of depression, among others, into the Kalmuck and south Caspian regions. The Caucasus underwent at that time a powerful uplift, and the sea here was quickly receding. The reduction of the sea area was not a result of the decrease of water masses, but of the increase of depths. The reduction of the evaporation area has naturally led to the lowering of the salinity of water, which in its turn resulted in the loss of a considerable part of the Akchagyl fauna and great changes in the forms which survived, as well as the invasion of the basin, at least its littoral shallow waters, by some fresh-water and lacustrine forms.

The tectonic processes affected also the further history of the Apsheron Sea. Considering that in the Lower Volga and Kalmuck region Apsheron shallow-water deposits attain considerable thickness (325—345 m), exceeding the possible depth of the sea, at which they could have been laid down, as well as the fact that the Apsheron Sea encroaches on the region of Eastern Manych, it is reasonable to assume that the whole Manych region was at that time undergoing submersion. This assumption is all the more probable that only via Manych could have been floated from the Black Sea to the Caspian region some groups of shells which imparted the peculiar character to the middle Apsheron fauna.

The connexion with the Black Sea region was evidently of short duration, as for the rest of its life period the Apsheron Sea had the character of an isolated basin. Its fauna was not enriched by newcomers from the outside and its specific composition was rapidly dwindling, while the number of specimens of separate species was rapidly increasing.

After the termination of this epoch which was comparatively uneventful from a tectonic standpoint, signs of a new intensification of the movement of the earth's crust became noticeable.

N. I. Andrussov(1) believed that these processes attained their maximum development at the very end of the Apsheronian era and were accompanied in the northern part of the basin by new submersion which again led—and again, probably, via Manych depression—to the connexion with the Black Sea region. This connexion resulted in the emigration of *Cardiidae* from the group *Didacna crassa* Eichw. which multiplied in great numbers in the Caspian during the Baku period and outsted some of the Apsheronian groups of species. However, part of the Apsheron fauna, more or less modified, has lingered on into our time.

Out of the number of 75 Apsheron species and varieties (V. P. Kolesnikov, «Apsheron Mollusks, Paleontology of USSR», manuscript) 12 show close relation to the modern Caspian ones, and 4 are still dwelling in the Caspian Sea (see the table). If we take into consideration that during the Quaternary likewise numerous migrations of mollusks from the Black Sea region occurred, it will become clear how diversified in its origin is the Caspian faunal

	Apsheron Sea	Caspian Sea
Species of Akchagyl origin	*Adacna plicata* Eichw. *Micromelania apscheronica* nom. nov. *Micromelania subcaspia* Andrus. *Clessiniola subvariabilis* Andrus. *Clessiniola major* Andrus.	*Adacna plicata* Eichw. *Micromelania turricula* Dyb. *Micromelania caspia* Eichw. *Clessiniola variabilis* Eichw. *Clessiniola triton* Eichw.
Species of lacustrine and riverine origin	*Dreissensia distincta* Andrus. *Dreissensia polymorpha* Andrus. var. *angustiformis* nom. nov. *Dreissensia polymorpha* Andrus. var. *lata* Andrus. *Neritina pallasi* Lind. *Neritina (Ninnia) schultzei* Grimm. *Nematurella apscheronica* n. sp. *Caspia matura* Bog. *Caspia apscheronica* n. sp.	*Dreissensia hyrcana* nom. nov. *Dreissensia polymorpha* Andrus. var. *marina* Pall. *Dreissensia polymorpha* Andrus. var. *elata* Andrus. *Neritina pallasi* Lind. *Neritina (Ninnia) schultzei* Grimm. *Nematurella eichwaldi* Kryn. *Caspia grimmi* Dyb. *Caspia kowalewskii* Dyb.
Species of Euxin origin	*Dreissensia eichwaldi* Andrus. *Monodacna minor* Andrus. *Pseudocatillus praelaeviusculus* Andrus.	*Dreissensia caspia* Eichw. *Monodacna caspia* Eichw. *Pseudocatillus laeviusculus* Eichw. (*Adacna laeviuscula* Eichw.)

complex. At the same time a study of such migrations would furnish very valuable material for the elucidation of the past of the Caspian Sea, which would contribute to a better understanding not only of its present but of its future as well. And the latter, being a problem of national-economic importance, is, as known, a matter of interest to numerous scientific institutions.

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PALEONTOLOGY

ON THE MECHANISM OF THE SKULL OF SOME OF THE LOWER *TETRAPODA*

By J. A. ORLOV

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On the skull structure of various vertebrates, its comparative anatomy, ontogenetic and phylogenetic development and adaptive plasticity a wealth of literature is available. At the same time not enough attention has been paid to the question of the skull as a definite mechanical construction, the separate parts of which are submitted to a rather variable mechanical strain under the action of the muscles of the neck, masticatory musoles, blows and shocks suffered by the skull, etc. On fish most complete data are contained in the work by Gregory(2). On land vertebrates interesting data and ideas are given by Marinelli (3,4,5) and Starck(6). However, not all of the assumptions advanced by Marinelli and Starck are born out by evidence. One of the reasons for that is that Marinelli, as well as other authors, either present too schematic a picture of the skull as a mechanical structure, or ignore the structures arising in the bone in response to the mechanical strain of a definite, or at least, dominant direction, whereas it is exactly the study of such structures that would contribute greatly to the elucidation of the trajectories of some of the «power» lines, as well as checking of some of the suggested assumptions.

The following is an attempt at an analysis of some elements in the mechanism of the skull, hitherto little if at all discussed in literature. Evidently, such a functional analysis would be an easy matter, had the outer surface of some or other bone reflected in any degree the mechanical function of this bone. In other cases such mechanical action might be reflected but in the inner structure of the bone.

An example of the former condition may be afforded by some *Anamnia* and *Sauropsida*. Of the enumerated lower vertebrates the external sculpture of the cranial bones (and lower jaw) of stegocephalians is described in greatest detail by A. P. Bystrov (1). However, no attempts have been made in literature to explain the functional value of this complex system of ridges and septa. Jaws (and teeth) of stegocephalians are typically prehensile organs for snapping at food. However, judging by the rather considerable development of fossae for the insertion and lodgment of adductor mandibulae muscles, the contraction of these adductors and hence the thrusts of the lower jaw against the upper were rather swift and powerful. A remote notion of the swiftness of these snapping movements may be gained when observing the feeding of a modern axolotl.

Considering the flat (dorso-ventrally) shape of the skull of stegocephalians, the complex system of vertical ribs on the dorsal surface of the skull must have been, in the manner of ridges on the dermal bones of many fishes, first of all in the facial part of the skull, playing the part of counterforts (king-posts, braces, «rods») reinforcing the durability of the skull and its resistance to a break, both when violently snapping at (bite of the jaws) and holding the prey. In the most simple and readily observable form this rôle of the ridges is manifest on the outer surface of «angulare» of stegocephalians, bracing at the base and as if supporting a considerable portion of the rest of the covering mandibular bones. The ridges fan-like diverge from the lower angle of «angulare» in the direction of the alveolar border of the mandible.

A somewhat more complex and at first sight disconcerting picture presents the arrangement of the ridges on the dorsal side of the skull proper. This is apparently due to the fact that the individual life of stegocephalians being of considerable duration and the sutures between separate bones of the skull practically of lifelong existence, the system of ridges must have been not merely constructionally adjusted to the durability of the skull as a whole, but equally a combination to meet this contingency and, moreover, to secure the individual durability of separate bones of the entire dorsal side of the skull tending to grow to some extent or other in different directions. Therefore, the course of traverses cannot possibly exhibit here such a «schematic» character. No doubt, we would meet a more simple sculpture in the skull of stegocephalians, were its dorsal side made up altogether, say, of one-two pairs of bones.

The foregoing assumptions as to the functional value of the structure of the outer surface of the skull bones (and jaws) of stegocephalians are fully justified by the following considerations:

a) Ridges of separate skull bones, approaching the border of bones they are borne upon, do not terminate bluntly at these borders, but are abutting against the corresponding ridges of the adjoining bones and thus seem to be continued into one another. As a result of this relationship, the entire surface of the skull is covered not with accidentally and disorderly scattered ridges, but with a complex and as if functionally and morphologically u n i f i e d system.

b) Ridges of separate bones of the facial part of the skull diverge radially from the center of ossification and retain this arrangement throughout the life of the animal. Such arrangement is evidently in adjustment to the demands made upon this particular bone as a definite constructive unit of the skull, otherwise a fundamental r e a r r a n g e m e n t of the ridges, resp. at a more advanced age of the animal—the formation of new ridges, would proceed in new directions.

c) With the general (ontogenetic) increase of the size of the stegocephalian skull and simultaneous increase of the muscular power of the adductors of the mandible, there inevitably follows the intensification of the strain upon separate bones of the facial part of the skull. This is probably the condition essentially responsible for the development with age of t r a n s v e r s e septa, connecting the ridges at the center of ossification acting at the same time as the center of trajectories of «power lines» for each bone.

d) With the growth of the skull the production by the periosteum of new outer layers on the dorsal side of the skull proceeds in such a manner, that the young ridges become not merely a «vertical» prolongation of old ridges, but are overlapping the latter and e x c e e d i n g them i n s i z e. This again agrees fully with the laws of mechanics, since for a large skull small

densely set ridges offer less constructive advantage than larger ones (broad and high), even though less numerous.

e) In spite of the small height of the described ridges, the mechanical value of their sum total for the facial part of the skull must have been rather high [in *Benthosuchus* the height of each of the ridges is about $^1/_4$—$^1/_3$ the thickness of the bone for quadratojugale, according to Bystrov([1], p. 79, Fig. 9)]. The dorsal side of the facial skeleton of stegocephalians, and of other vertebrates as well, serves mainly for compression, the ventral one—for extension. It is owing to these conditions, possibly, that in stegocephalians the rearrangement of the skull bones occurs on the dorsal side, i. e. in the bone layer formed by ridges (the «normal» general work «for compression» evidently furnishes the bone one of the stimuli for rearrangement). On the other hand, the internal «basal» plate of the skull roof bones shows no such tendency to rearrangement.

Having set forth the above considerations, I do not assert that the very appearance of the sculpture on the skull bones, the mandible (as well as the clavicle and interclavicle) in stegocephalians was primarily the result of the above-mentioned conditions of the mechanical stress upon the bones concerned. It is quite probable that the sculptured outer surface was inherited by stegocephalians from crossopterygian fishes of various ancestry; however, it seems beyond any doubt that this sculpture was subordinated to the mechanism (or adaptive plasticity) of the skull as a whole.

The above need not be interpreted in a way that the arrangement of ridges observable on the skull of stegocephalians is the only possible solution of the constructive problem. However, with this particular arrangement of centers of ossification and the given orientation of growth of the bones, giving rise to the «zones of intensive growth»([1]), the existing arrangement of ridges apparently corresponds to the direction of «power lines» and may be regarded as the best solution of the constructive problem.

The brain capsule in stegocephalians which remained partly cartilaginous, could not reflect the anatomy of the brain itself to such an extent, as this is the case in mammals, since in amphibians the brain is separated by considerable interspaces from the walls of the brain capsule. But apart from that, the relatively negligible size of the brain compared with the immensely powerful neurocranium makes assumption, that there is but a slight change for any connexion between the external mechanical stress upon the brain capsule and the shape of the brain. Exactly the opposite is true respecting the relations observed in the skull of small mammals, namely *Carnivora* of the type of martens and cats. A short, high and rounded facial skeleton, owing to its general shape, produces an arch capable of resisting the powerful pressure from below when grasping the prey and snapping the mouth. The secondary, often slightly arched palate increases this durability (cf. also Marinelli, 1931, 1938), and the character of the construction of the entire skull as a whole is such, that with an identical length of the facial part of the skull, or of the wide gape of the mouth, the facial part of the skull of the mammal is so much more durable than in the stegocephalian and does not require a system of low, but numerous counterforts.

The matter assumes an altogether different aspect in the skull of small carnivora, likewise in regard to the brain capsule, which is subject to pressure: a) of the brain internally; b) permanently of muscles of the jaws owing to the tonus of m. temporalis; c) increased, irregular, periodical—during bitting, cutting with carnivorous teeth; d) violent, sharp when snapping at the prey, fighting with enemies, etc. The part played by m. temporalis in this pressure on lateral walls of the capsule externally is particularly great. In the case of a strong m. temporalis in *Carnivora* with

a thin brain capsule (in small forms) the rôle of counterforts, situated on the inner side of the lateral walls of the capsule, may be played by juga cerebralia.

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PALEONTOLOGY

A NEW GENUS *SYNARTINSKIA* FROM THE FAMILY *MEDLICOTTIIDAE*

By V. E. RUZHENCEV

(Communicated by A. A. Borissiak, Member of the Academy, 22. IX. 1939)

The ammonites which are distinguished by me under the name *Synartinskia* were formerly referred by different authors either to the genus *Propinacoceras*, or to *Artinskia*. The study of Uralian representatives of the family *Medlicottiidae* has revealed that for distinguishing genera within the family the external saddle with its adventitious lobes is of great importance. As known, in all representatives of the genus *Propinacoceras* the siphonal side of the external saddle has no adventitious lobes. In the genus *Artinskia* the siphonal side is indented by two adventitious lobes. It should be noted that this peculiarity is retained in all representatives of the genus throughout a long phylogenetic period [*A. irinae* Ruzh. from the Upper Carboniferous, *A. nalivkini* Ruzh. from the Sakmarian, *A. artiensis* (Grünew.) from the Artinskian]. The evolution within the genus proceeded at the expense of other characters. In the most primitive *Medlicottia* on the siphonal side of the external saddle three adventitious lobes are present. The starting of this genus from *Artinskia* is just concurrent with the appearance of the third adventitious lobe, which stresses once more the importance of this at first sight minor character.

Finally, in a number of representatives of the family *Medlicottiidae* only one adventitious lobe is observed on the siphonal side of the external saddle. It was this structural peculiarity that led to the assignment of the ammonites which possessed this feature either to the genus *Propinacoceras*, or to *Artinskia*. The specific name of the first of such forms, «*Propinacoceras*» *transitorium* Haniel, ought to suggest an transitional position of the species. In my opinion, such an interpretation of the fact is incorrect. The representatives with one adventitious lobe do not belong in the phylogenetic branch of *Artinskia*, and should be, consequently, distinguished as a special genus.

Genus *Synartinskia* gen. nov.

1890. *Propinacoceras*, Karpinsky (part.). Uber die Ammoneen der Artinsk Stufe, S. 72.
1915. *Propinacoceras*, Haniel (part.). Die Cephalopoden der Dyas von Timor, S. 34.
1927. *Propinacoceras*, Smith (part.). Jaarboek van het Mijnwezen in Ned.-Indie, Verh., 1926, I, p. 17.
1936. *Artinskia*, Miller, Jour. Paleont., vol. 10, № 6, p. 490.
1937. *Artinskia*, Plummer et Scott (part.). Univ. Texas Bull. 3701, p. 91.

Diagnosis. Conch discoidal, involute, with flat lateral sides. Ventral side adorned with two rows of tubercles. Suture line complex. Its external portion consists of a narrow trifid ventral lobe and a large number of lateral lobes, several initial of them being bifid. The broad external saddle indented by adventitious lobes. On the siphonal side of the saddle just one adventitious lobe is present.

Genotype, *Synartinskia principalis* gen. et sp. nov. Ultugan-sai ravine; Aktubinsk region, Sakmarian.

The new genus differs from *Propinacoceras* in the possession of one siphonal adventitious lobe. As known, in representatives of the genus *Propinacoceras* the siphonal side of the external saddle remains undivided throughout all stages of development. The main distinction of our genus from *Artinskia* is in the lesser number of adventitious lobes. On the siphonal side of the external saddle of *Artinskia* there are two adventitious lobes, and on that of *Synartinskia* there is only one. The number of lateral adventitious lobes in representatives of the genus *Artinskia* is also greater.

The phylogeny of the family *Medlicottiidae* is far from being ascertained in all details. The origin of the genus *Synartinskia* is also an unsettled problem. In its morphological features the genus occupies an intermediate place between *Artinskia* and *Propinacoceras*, owing to which fact its representatives have been alternately classed with one of the genera named, or another. We are aware now that representatives of the genus *Artinskia* lived throughout the three ages, Upper Carboniferous, Sakmarian and Artinskian. The genus *Propinacoceras* has hitherto been found to occur only in the Artinskian and in younger strata of other countries. All the known representatives of the genus *Synartinskia* have come from the Sakmarian or from contemporaneous sediments. In addition, one species has been discovered in Bitauni beds, Timor island. Now we come across the following interesting fact. Forms which in comparison with *Synartinskia* seem to be more advanced, viz. *Artinskia*, are represented already in the Upper Carboniferous. On the other hand, forms which appear to be less advanced than our genus, viz. *Propinacoceras*, have so far been recorded from the Artinskian and from higher strata. This suggests an assumption that the genus *Synartinskia* belongs in a special branch within the family *Medlicottiidae*, as well as *Propinacoceras*. However, the roots of these branches (this is particularly true with the genus *Synartinskia*) have not as yet been ascertained. It is comprehensible, hence, that the necessity of separating the new genus *Synartinskia* is dictated not merely by its morphological features, but also by phylogenetic considerations.

It seems very likely that *Propinacoceras sakmarae* (Karp.) is referable to our new genus. It is to be regretted that Karpinsky had no opportunity to study in detail the outline of the external saddle of this species, the generic membership of which is consequently rather uncertain. In addition to the genotype the following forms may be referred with certainty to the genus *Synartinskia*: «*Propinacoceras*» *transitorium* Haniel (Bitauni beds), «*Artinskia*» *whortari* Miller (Big Blue formation), «*Artinskia*» *adkinsi* Plummer et Scott (Wichita group, Admiral formation), and «*Artinskia*» *electraensis* Plummer et Scott (Wichita group, Clyde formation).

Synartinskia principalis gen. et sp. nov.

Shape (Fig. 1, *a—c*). Conch discoidal, involute, with umbilicus entirely closed. Lateral sides extremely broad, almost flat. Whorl attains its maximum width in the mid-portion of lateral sides, closer to the umbilicus. The width decreases markedly towards the umbilicus, and but negligibly so in the opposite direction. In proximity to the ventral border the lateral

sides become somewhat concave. The ventral side consists of three portions: two extreme broad keels ornamented with tubercles, and the separating narrower furrow. The living chamber of large individuals is longitudinally sinuous; along the ventral side alternate, equally broad, highly convex and concave zones are observed.

Sculpture. The test layer has been poorly preserved, and details of ornamentation are consequently unknown. In any case, a statement may be made that the lateral sides of the shell are almost smooth, and it is only near the ventral border that thickly spaced and very delicate transverse striae make their appearance. They run across the concave zone, being somewhat oblique in position. Their outwardly directed terminations are greatly displaced towards the aperture. The above transverse striae are quite readily discernible not on the conch only, but also on the mould. Along the ventral keels numerous strictly opposite tubercles are placed. They are rounded on the whole length of the conch, except the living chamber where they become elongate; there they are also continuous on the lateral sides as far as the concave zone. There are 52 tubercles to the ultimate volution of the holotype at the diameter of 47.0 mm. In a juvenile specimen, at the diameter of 20.7 mm, 50 tubercles have been counted. It follows, hence, that the number of tubercles scarcely varies with growth.

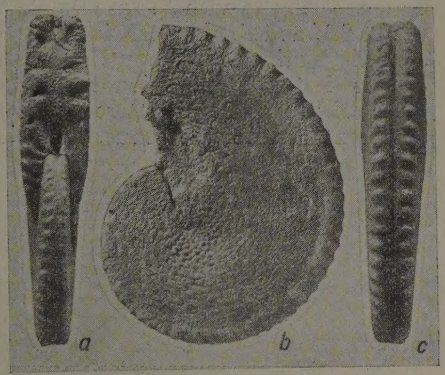

Fig. 1. *Synartinskia principalis* gen. et sp. nov. Three views of the holotype (× 1).

Suture. In Fig. 2, *a* the suture of the holotype is shown at the width of the volution of 8.4 mm (H =25.0 mm). The ventral lobe is long, narrow and trifid, the middle prong being larger than the outside ones. The external saddle is quite broad. Its siphonal side is cut by one narrow, entire, adventitious lobe, oblique in position, located almost at the very summit of the saddle. Its inner side is indented by a very broad and deeply bifid adventitious lobe which is much lower in position than the siphonal one. At the saddle summit two more adventitious lobes are observed, the ends of which meet fairly closely. They are separated by a rounded adventitious saddle. The first lateral lobe is asymmetrical, divided into two long pointed prongs. Its base is much lower in position than that of the next lobe. The second, third and fourth lateral lobes are also distinctly bifid. They but slightly decrease in size umbilically. The adventitious saddles separating the prongs are narrow, but somewhat rounded at the summit. The fifth lateral lobe is markedly smaller than the fourth, being also bifid. The sixth lateral lobe is by far smaller than the preceding one and bifid. The remaining lateral lobes are undivided, basally rounded; they gradually decrease in size in the umbilical direction. The number of all lateral lobes totals eleven, of which six are pronged and five entire. On the umbilical wall one small lobe and one broader saddle are observed.

Fig. 2, *b* shows the suture line of another mature individual. In this case the lateral adventitious lobes are distinguished by the greater width. It can be seen on the left side of the conch that the lower branch of the adventitious lobe is in turn minutely bifid. The adventitious lobes at the saddle summit are less developed than in the holotype. Yet, the suture retains

the same general character with all distinctions typical of the species in question.

Dimensions:		*D*	*H*	*W*	*H*:*D*	*W*:*D*
(Holotype)	I	47.0	28.8	9.6	0.61	0.20
	II	20.7	12.8	4.4	0.62	0.21

Relation to Other Species. The species described is distinctly different from all other representatives of the genus *Synartinskia*. In comparing it with *S. transitoria* (Han.), *S. whortani* (Miller), *S. adkinsi* (P. et S.), and *S. electraensis* (P. et S.), in each case a number of very essential distinctions in the outline of the suture may be pointed out. But one fact is first of all conspicuous, that in *S. principalis* the positions of bases of the first and second lateral lobes are entirely different from that in other representatives of the genus. In the former case the base of the first lateral

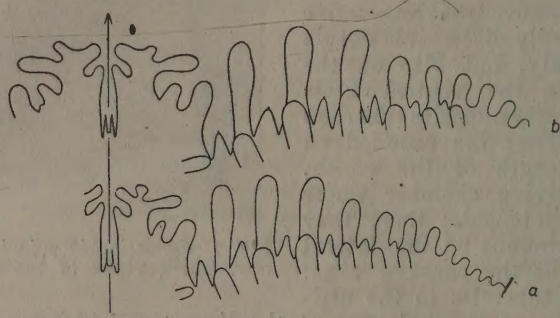

Fig. 2. *Synartinskia principalis* gen. et sp. nov.: *a*—holotype; suture at *H*=25.0 mm (×2); *b*—paratype; suture at *H*=27.5 mm (×2).

lobe is much lower in position, while in the rest it is somewhat higher than the base of the second lateral lobe. Moreover, not a single species shows such a large lateral adventitious lobe as one observed in *S. principalis*. But in all the other above-mentioned representatives of the genus the total number of adventitious lobes on the inner side of the saddle is one more than in *S. principalis*.

Should we prove that *Propinacoceras sakmarae* (Karp.) belongs actually in the genus *Synartinskia*, the named species would be more closely related to our new forms than any other one. In *P. sakmarae*, as in our case, the base of the first lateral lobe is much lower in position than that of the second lateral one. Yet, the general outline of the external saddle in the two species named is different.

Occurrence. 15 specimens, mostly in fragmented condition, have been found in the sandstones of the Sakmarian stage, Ultugan-sai ravine, Aktasty river, Aktubinsk region.

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